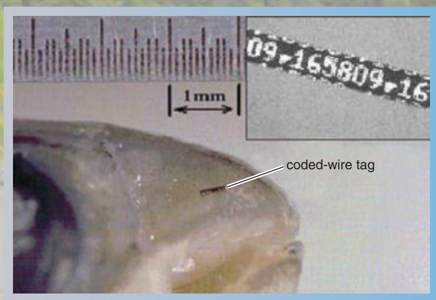
Juvenile Salmonid Composition, Timing, Distribution, and Diet in Marine Nearshore Waters of Central Puget Sound in 2001 - 2002.

August 2004



Lake Washington Cedar Sammamish Watershed

Green/Duwamish and Central Puget Sound Watershed

King County
Department of Natural Resources and Parks

King Conservation District

JUVENILE SALMON COMPOSITION, TIMING, DISTRIBUTION, AND DIET IN MARINE NEARSHORE WATERS OF CENTRAL PUGET SOUND IN 2001-2002

August 2004

Prepared for:

Lake Washington • Cedar • Sammamish • Watershed

WRIA 8
Steering Committee

King County

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GREEN/DUWAMISH AND CENTRAL PUGET SOUND WATERSHED

WRIA 9
Steering Committee

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Juvenile Salmon Composition, Timing, Distribution, and Diet in Marine Nearshore Waters of Central Puget Sound in 2001-2002

Funded by:

WRIAs 8 and 9 Watershed Forum of Local Governments through the
King Conservation District and King County

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Cover photos (Clockwise from middle)**:**

Historic seining photo: Vashon Maury Island Heritage Association
Sampling crew and gear: King County
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EXECUTIVE SUMMARY

The listing of Puget Sound Chinook salmon as *threatened* under the authority of the Endangered Species Act (ESA) prompted a number of local, state, and federal resource management agencies to identify and evaluate factors affecting the decline of salmon. Early in this process, the King County Department of Natural Resources and Parks recognized that much was not understood about the early life history of salmon in Puget Sound. This was especially true of time spent in marine shoreline areas outside of river mouth estuaries. The early life stages in the marine environment are considered critical to the survival and productivity of salmonids. Yet, little is known about the species composition, timing, distribution, and diet of salmonids in marine nearshore waters of central Puget Sound. To address these gaps in our understanding, a pilot study was conducted in 2000, and followed up with the 2001 and 2002 marine nearshore salmonid surveys presented in this report.

The central purpose of the nearshore salmonid surveys was to investigate the use of marine nearshore waters by juvenile salmonids within the study area (central Puget Sound). Sampling sites were selected throughout the study area (WRIAs 8 and 9, including Vashon/Maury Islands), within the boundaries of King and south Snohomish Counties. A 37 meter x 2 meter floating beach seine was used to collect fish, which were measured, weighed, and checked for coded wire tags and adipose fin clips (to distinguish hatchery from wild fish and origin of tagged hatchery fish). Gut contents were collected in order to determine diet composition. Relevant environmental data were also collected to characterize habitats at each sampling location. Sampling was conducted between May and October 2001, and April to December 2002.

SALMONID CATCH

From the 591 sets made during the study period, nine salmonid species were represented in the cumulative catch. Chum salmon were the most abundant, followed by pinks, Chinook, coho, cutthroat, sockeye, steelhead, Bull trout, and Atlantic salmon.

In general, one could expect to find salmon in the nearshore at any time of the year. However, while there are overlaps in the timing of use by individual species of juvenile salmonids, there are also distinct differences in peak abundance and persistence of each species in littoral and sublittoral areas (i.e., shallow marine nearshore waters sampled with the beach seine). Although earlier peaks of some species were most likely missed due to the timing of the sampling, changes in abundance over time were recorded. Pink salmon abundance peaked in April and was absent from the catch after May. Chum salmon abundance was also high in April and May, but dropped off dramatically after July . Coho abundance also peaked in May and they continued to be present in the catch into October. Chinook salmon were caught during the entire sampling period, with a peak abundance in June. In addition to being the most persistent salmonid found in shallow marine nearshore waters, Chinook were also the most broadly distributed, being found at all sites sampled.

There was generally no significant difference in Chinook abundance between sites. Of particular importance is the fact that there was no significant difference between the catch of Chinook at island sites compared to mainland sites. Since Vashon and Maury Islands have no Chinook-bearing streams, the presence of Chinook at these sites would necessitate crossing an open, deep water channel away from the protection of the nearshore environment. Therefore, one would have expected to find larger numbers of Chinook at mainland sites relative to island sites. This observation suggests that Vashon and Maury Islands are important considerations in nearshore salmon recovery efforts even though the area does not contain any Chinook-bearing streams.

CODED WIRE TAGGED SALMONIDS

One inherent problem with attempting to characterize the nearshore timing, distribution, and abundance of juvenile salmonids is that multiple stocks originating from multiple stream systems throughout the region mix within Puget Sound. In addition, the large numbers of hatchery fish released into the system combined with the lack of marking 100% of hatchery releases greatly inhibits the ability to distinguish hatchery from wild fish and, subsequently, characterize timing and distribution patterns of wild fish. Also, the relatively low proportion of coded wire tagged fish among hatchery releases reduces the ability to distinguish the various stocks found in the study area. Hatchery Chinook greatly outnumbered (75 percent of the catch in 2002) Chinook classified as "wild," and their occurrence in space and time was similar to "wild" Chinook.

The origin of a portion of the catch was determined by analyzing coded wire tags (CWT). Combined, a total of 22 hatcheries, located in 13 watersheds were represented in the recaptures of tagged fish. Although recaptures of tagged fish released from south Sound hatcheries were anticipated, patterns of distribution from the north Sound hatcheries into central Puget Sound and across the open, deeper waters of Puget Sound (both east-west and west-east) were observed. Salmon leaving their natal stream don't necessarily head immediately in a northerly direction out of Puget Sound. For example, 86 percent of the CWT recoveries from the Soos Creek Hatchery were recovered south (and southwest – Vashon/Maury Islands) of the Duwamish River. There were also CWT recaptures from distant hatcheries to the north and west (e.g., Marblemount, Samish, Lummi Bay Sea Ponds, Dungeness, Port Gamble Bay, Grovers Creek) that were not anticipated. These observed patterns raise many questions about distribution and whether or not movement is entirely volitional, or may be influenced by other forces, such as wind and currents.

SALMONID DIET

Stomach contents of 819 Chinook salmon, 89 coho salmon, and 56 cutthroat trout were analyzed to determine diet composition. Chinook diet samples were analyzed from 410 individuals in 2001 and 409 from 2002 at 16 different sites. In both years, terrestrial insects numerically dominated Chinook diets. Gravimetric (weight) composition was similar between years in all ecological categories (benthic/epibenthic, planktonic/neritic, terrestrial/riparian) and varied by size fish and season. For juvenile Chinook salmon in the smallest size class examined (<90 mm FL), benthic and epibenthic prey dominated diet by weight. Chinook in the next three size classes (90-149 mm FL) had dietary components that were more evenly distributed in the three ecological categories and insects became a more dominant prey item with increasing size, along with benthic and epibenthic prey. The largest size classes of salmonids fed on planktonic and neritic organisms. There were also distinct seasonal patterns in diet composition. Polychaete worms dominated the <90 and 90-149 mm size classes of juvenile Chinook prey early in the sampling season (i.e. May), but were replaced by other prey organisms later in the season. For example, in September, insects made up over 50% of the prey weight in Chinook from 90-149 mm size class and over 80% of the >150 mm size classes. Diets were also similar between geographic locations, but some differences were detected. There was also a great deal of similarity between diets of juvenile Chinook classified as hatchery and "wild."

Stomach contents from a total of 89 juvenile coho salmon from 12 sites were analyzed for diet composition, including 51 individuals from 2001 and 38 from 2002. In both years, the majority of coho diets consisted of plankton (e.g., crab larvae, copepods, amphipods). By weight, prey composition was dominated by fishes, especially larval and juvenile sand lance.

Stomach contents from a total of 56 cutthroat trout from 12 beaches were analyzed for diet composition, including 47 individuals from 2001 and 9 from 2002. Fish ranged in size from 130-441 mm (FL).

Cutthroat trout diets were dominated by fish (mostly non-salmonids) in both years. Other taxa found in significant numbers included insects, crab larvae, amphipods, copepods, and isopods. Prey composition was dominated by fishes for all cutthroat size classes, with the exception of the 150-199-mm-size class, where terrestrial/riparian insects were abundant.

STUDY IMPLICATIONS

Salmon recovery requires the recognition of the linkages between salmon and their habitats, which cross jurisdictional and ecological boundaries. The broad geographical distribution of salmonids found in this study, originating from 13 watersheds and 23 hatcheries, and the high component of terrestrial insects in the diet of juvenile Chinook, illustrate the linkages between aquatic and terrestrial ecosystems and the importance of managing the landscape from a regional perspective. The similar timing, similar distribution, and similarities in diet between hatchery-raised and wild fish suggest that they are likely competing for the same resources.

ACKNOWLEDGEMENTS

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TABLE OF CONTENTS

TABLES

FIGURES

SECTION 1: INTRODUCTION

1.1. Overview

Puget Sound supports over 200 species of marine fishes, many of which depend upon the productivity and critical habitat attributes found in the marine nearshore ecosystem. The nearshore and estuarine environment is especially important for anadromous salmonids, representing a critical component of their life histories (Thom 1987; Simenstad *et al.* 1982; Spence *et al.* 1996; Williams *et al.* 2001).

In Puget Sound, juvenile salmon use the nearshore for migration, nursery areas, feeding, and refugia from predators. Therefore, the quality and quantity of habitat available for juveniles is a critical factor as they leave their natal streams and prepare for life at sea, and has been identified as key to the survival and perpetuation of the species (Duffy 2003). The Beamish *et al.* "critical size – critical period" hypothesis (1998) suggests that, aside from predation, the "condition" of juvenile salmonids (i.e., growth and growth rate) is critical for surviving through late fall and early winter of their first year in the marine environment. Reviews of salmonid biology by Meyer (1981) and Aitkin (1998) also illustrate the importance of early marine residency. To date, little information has been synthesized on the utilization of nearshore habitats by salmonids.

1.2. Background

Despite the economic importance, attention, and levels of research dedicated to learning more about Pacific salmon, stocks have declined precipitously in the past 20 years. Nehlsen *et al.* (1991), in their review of the status of individual stocks of Pacific salmon in Washington, Idaho, Oregon, and California, identified at least 106 previous extinctions, 101 stocks of salmon at high risk of extinction, 58 stocks at moderate risk of extinction, and 54 stocks of special concern. Anderson (1993) states that the natural productivity of Pacific salmon south of British Columbia has declined by approximately 80%. In Puget Sound, Bottom *et al.* (1998) found that the catches of wild coho and Chinook salmon have declined by 43% and 61%, respectively. As a result, in the Puget Sound Evolutionarily Significant Unit (ESU), summer chum, summer/fall Chinook, and bull trout have been listed as *threatened* under the authority of the Endangered Species Act (ESA), and coho are a candidate for listing. Urbanization, the extensive alteration and degradation of nearshore ecosystems, and the ESA listings of Puget Sound Chinook salmon and bull trout have increased the need for an improved understanding of the marine life phases of salmonids and the implications for other marine fishes.

While a number of studies (e.g., Fresh et al. 1981; Simenstad et al. 1982; Healy 1982a,b; and others) provide the basis of the understanding of salmonid early marine life history, until recently few studies have been conducted outside of river-mouth estuaries, especially in the Central Puget Sound Basin. The studies of fishes in marine nearshore waters of Puget Sound have been sporadic and are inadequate for detailing critical information on juvenile salmon timing, distribution and other characteristics of early marine residency. Only recently have other investigators begun to collect the types and levels of information needed for characterizing juvenile salmon in the nearshore (e.g., Duffy 2003).

In the summer of 2000, King County initiated this study to advance our understanding of the importance of the nearshore environment to juvenile salmonids. We focused on the specific geographic area of King and South Snohomish Counties. This information is especially important for expanding the body of knowledge upon which watershed planning, wastewater planning, salmon recovery planning and other resource management efforts are based.

1.3. Purpose and Study Objectives

King County Department of Natural Resources and Parks conducted beach seine surveys in 2001 and 2002 in an effort to examine the timing, distribution, and composition of marine fishes in the nearshore waters of Central Puget Sound (Figure 1-1). With particular emphasis on juvenile salmonid biology during early marine residency, data were collected on salmonid dietary composition, size classes, weights, and the relative composition of hatchery and "wild"[1] fish. Specific project objectives were to:

- sample a broad geographic area within King and south Snohomish Counties for determination of differences in salmonid species composition (timing, distribution and abundance),
- measure temporal and spatial distribution of nearshore salmonids at specific sites,
- determine prey composition and important prey items in their diet,
- estimate proportion of hatchery and "wild" salmonids, and
- determine point of origin/release, distribution, movement patterns, time-at-large, and growth estimates using coded wire tag (CWT) recoveries.

1.4. Study Area

Puget Sound is a deep, elongated glacial fjord-like estuary located in northwest Washington State. The location and form of Puget Sound is the product of glacial and geological processes occurring over the last few hundreds of millions of years (Burns 1985). The advance and retreat of glaciers over the millennia carved out the lowlands, which became flooded with oceanic waters through the Strait of Juan de Fuca to form the inland sea now called the Puget Sound/Georgia Basin. Freshwater flows into Puget Sound from numerous rivers and streams along its shores and mixes with oceanic water supplied by the Pacific Ocean. The Sound consists of four major basins, based on natural sills that influence tidal mixing of deep water between basins. The study area lies within the Central Basin, which contains the greatest average depth (~100m) and the deepest point (>280m) in Puget Sound. Additional descriptions of the physical and oceanographic properties of this area can be found in Burns (1985), Strickland (1983), Ebbesmeyer (1984), and Williams et al. (2001).

In addition to being a dynamic estuary of national significance, Puget Sound has experienced dramatic changes over the last century as a result of human influences. The Central Basin is the most heavily urbanized part of Puget Sound and human activities have significantly modified the marine shorelines in this area, taking a toll on the living resources and habitats that support them.

Sampling sites were located within central Puget Sound (Figure 1-1). The general area of sampling was determined by watershed boundaries (areas of responsibility for watershed and salmon recovery planning) and included Watershed Resource Inventory Areas (WRIAs) 8, 9, and a portion of 15. In accordance with statewide salmon recovery planning efforts, Vashon and Maury Islands (WRIA 15) are treated as part of WRIA 9.

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[1] The term "wild" is used to describe salmonids that do not have a coded-wire tag and have an adipose fin. This is an attempt to differentiate hatchery-raised salmon from wild salmon, but is compromised by the fact that not all hatchery fish are fin-clipped and/or CWT.

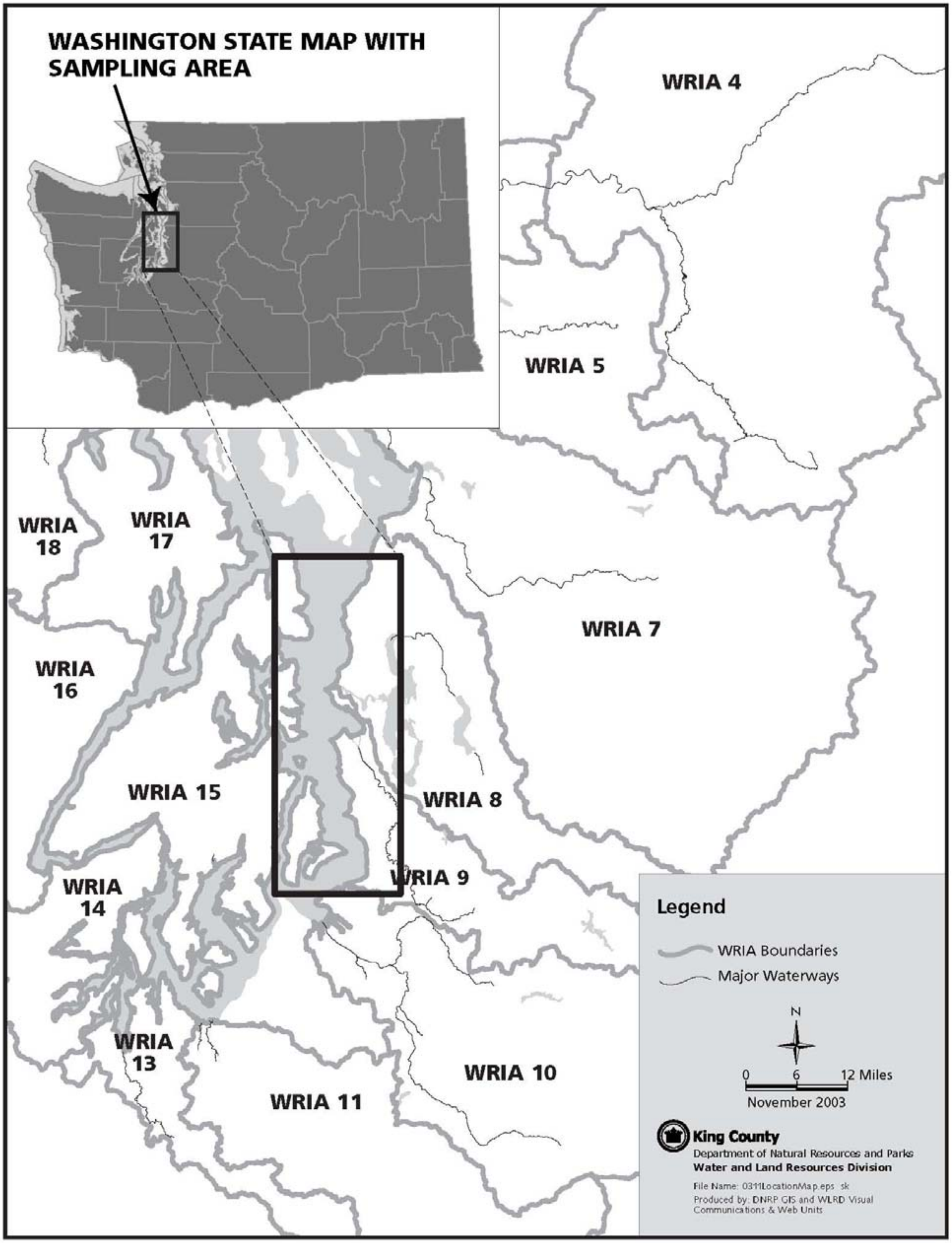

Figure 1-1. Study sampling area and locator map.

SECTION 2: METHODS

2.1. DATA COLLECTION AND INTEGRATION

The data collected, analyzed, and integrated into this report originated from three independent studies initiated by King County; 2001 and 2002 Marine Nearshore Fish Surveys, Bull Trout Surveys (Taylor 2002), and the Core Areas Study (Martin and Shreffler 2002). The marine nearshore fish surveys served as a basis for all other data collection and provided the bulk of the data presented in this report. The field sampling for each study was based upon protocols and procedures developed by King County Department of Natural Resources and Parks for their marine nearshore fish surveys, using a standard beach seine following the methods described in Simenstad et al. (1991). Although each independent study was designed with different primary goals, discussions during the planning process allowed for later data integration, analysis and reporting. Sampling sites for each study (Figure 2.1) were all located within Central Puget Sound, and combine for a total of 28 sites. A summary of the studies used in this report is provided in Table 2.1.

Table 2.1. Summary of studies that contributed data for this report.

Study	Survey period	Frequency	Geographic Area
King County Nearshore Marine Fish Surveys	May through Oct, 2001	Bi-weekly	WRIAs 8 & 9 (South Snohomish County and throughout King County), 13 sites
	May through Dec, 2002	Bi-weekly	WRIAs 8 & 9 (Throughout King County), 12 sites
Core Areas Study	May 13 through May 31, 2002	Bi-weekly	WRIA 9 (Vashon/Maury Islands), 10 sites
Bull Trout Surveys	April 17 through May 22, 2002	Weekly	WRIA 8 (South Snohomish County and North King County), 5 sites

2.1.1. Marine Nearshore Fish Survey

The selection of sites for the marine nearshore fish survey was based upon public access and habitats that are conducive to operating a beach seine. Although some of these beaches were associated with small coastal streams, none were located within river mouth estuaries. A set of sites was selected for consistent sampling within and between years. In order to increase diversity of sites based on observed differences in physical characteristics, a few sites for opportunistic, less frequent sampling were also included.

2.1.2. Independent Studies

The primary goal of King County's Bull Trout Study was to survey both freshwater and marine nearshore areas to determine presence of bull trout (*Salvelinus confluentus*). Site selection for marine sampling was based upon ease of access and local (anecdotal) information about bull trout occurrence in northern King County. Five sites were selected: Picnic Point, Meadowdale, Edmonds, Richmond Beach, and Deer Creek. Three of the five sites were sampled weekly between April 17, 2002 and May 22, 2002. Deer Creek and Edmonds were sampled twice during this period. This was a term-limited study due to timing and funding constraints. The study area overlapped with other nearshore fish surveys and data were collected on other marine fish and environmental parameters to make the data useful for this synthesis.

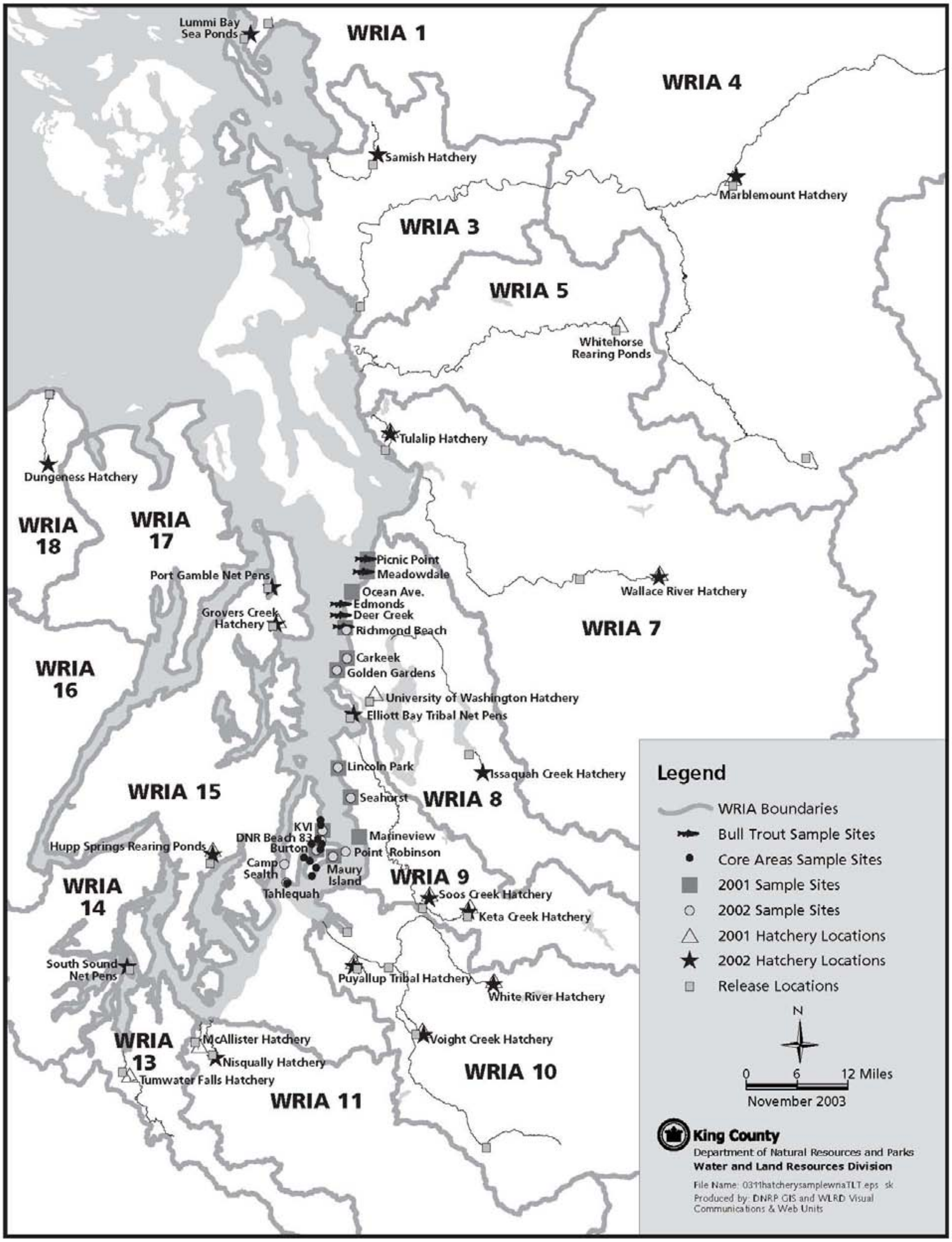

Figure 2.1. Hatchery, release, and sample locations. For final insert PDF--# within the legend needs to be changed

In general, all captured fish were identified and enumerated. A subsample of all salmonids (30 minimum, if available) and nonsalmonids (10 minimum) were measured in fork length (FL) or total length (TL), depending upon the species. In addition, CWT salmon (approximately five from each site/day) and a subsample of gut contents were collected for later analysis. Both quantitative and qualitative environmental data were also collected as described below. The details of this study can be found in Taylor (2002).

The purpose of King County's Core Areas Study was to develop a core area identification protocol for rivers, estuaries, and marine nearshore waters of King County. The protocol was based on theoretical relationships between spatial patterns of salmonid abundance and the geomorphic and hydrographic attributes of channels, estuaries, and marine shorelines that tend to create those patterns. The field sampling on marine shorelines for this study was designed as a pilot study to inform future core areas model development and was based upon established protocols and procedures. The ten sampling sites were selected at random, but they were based upon substrate, exposure, slope, and dominant aquatic vegetation. All marine core area sites were located on Vashon and Maury Islands due to a lower concentration of shoreline developments/modifications than mainland King County. In general, it was assumed that salmonid distribution and abundance would vary based on habitat characteristics. Sites were sampled over two, three-day sampling periods: May 13-15 and May 29-31, 2002. All salmonids in the catch were identified and enumerated. At least 30 individuals of each species were measured (fork length) and coho (*Oncorhynchus kisutch*) and Chinook (*Oncorhynchus tshawytscha*) were checked for CWT. A limited number of CWT fish and gut contents were collected for later analysis. Nonsalmonids were also identified and enumerated. The details of this study can be found in Martin and Shreffler (2002).

2.2. FIELD SAMPLING AND FISH DATA COLLECTION

Marine nearshore fish surveys occurred between May and October 2001, and between April and December 2002. Sampling sites varied between years, with seven sites sampled consistently during both years. Each site was sampled during daylight hours (with the exception of one night seining event in October, 2001) at variable tidal elevations. In May and June, 2001, three non-overlapping sets of the beach seine were made at each site. During the remainder of the study period, two sets were made at each site in order to complete three site surveys within a single day. If drift vegetation clogged the net, or if debris and/or large rocks interfered significantly with the set, the haul was abandoned.

Sampling was performed with a floating beach seine. The beach seine (commonly called a "Puget Sound beach seine") was designed according to the specifications from Simenstad et al. 1991. The equipment consisted of a 37 m long by 2 m high seine with tapered wings (2.56 cm stretch mesh) and a bag (0.6 m wide by 2.4 m deep by 2.3 m long, 0.6 cm stretch mesh) centered between the wings.

The net was set parallel to, and approximately 30 m from, shore from a motorized vessel. Two crews, standing about 40 m apart on the beach, then hauled the net to shore at an approximately equal rate. When the net was approximately 10 m from shore, the net opening was closed to approximately 12 m and retrieval was concluded. Fish were then sorted and collected for data processing.

Fish were maintained in aerated buckets of seawater until they could be measured. All fish were identified to the lowest taxonomic classification that could be made with confidence and then counted. A random subsample of each species was measured on a wetted measuring board. In 2001, a minimum of 10 fish of each species was retained for measurements of FL or TL. In 2002, a minimum of 30 individual fish of each species was retained for measurements (or all fish if counts were less than 30 for an individual species) to improve statistical robustness. Although data for all fish species were recorded, this report is limited to results of the salmonid catch only.

In 2001 and 2002, all coho, Chinook, chum (*Oncorhynchus keta*), steelhead (*Oncorhynchus mykiss*), cutthroat (*Oncorhynchus clarki*), and sockeye (*Oncorhynchus nerka*) were measured for length (pink salmon (*Oncorhynchus gorbuscha*) were captured only in 2002), and weights were collected for a subsample of salmonids in 2002. Once sedated with tricaine methylsulfonate (MS-222), salmonids were identified to species, measured to the nearest mm (FL) and allowed to recover. Most Chinook and coho salmon were checked for adipose fin presence or absence and recorded as clipped, unclipped, or unknown. Chinook and coho were checked for CWTs beginning in early June 2001 and early July 2001, respectively. Fish that were not fin clipped and were not checked for CWTs were classified as "unknown" instead of hatchery or "wild."

In 2002, all Chinook and coho were checked for CWTs throughout the sampling season. In addition, Chinook were scanned for Passive Integrated Tags (PIT). In 2002, most subsampled salmonids were weighed to the nearest 0.1 gram (g). All CWT fish from both years were retained, labeled, and preserved for transport to the Washington Department of Fish and Wildlife CWT lab in Olympia for tag extraction and decoding. Origin and recapture locations were then mapped to show spatial distribution of CWT fish. Relative proportions of marked and unmarked fish were analyzed to determine composition of hatchery and "wild" fish contribution to the standing stock at each location over time. Time-at-large, distance traveled, rate of travel, and growth were also determined, based upon available data.

Diet samples were collected in 2001 and 2002. Early in 2001, a subsample of whole salmonids was collected and preserved in 10 percent solution of buffered formalin. This procedure was soon replaced with gastric lavage to avoid sacrificing fish. Stomach contents were flushed directly into a sample collection container, which was placed inside of a fine-mesh filter used to catch any contents that spilled over the collection container. The samples were labeled, preserved with 90% ethanol, or formalin solution, and archived for later analysis. All samples (i.e., whole fish, stomachs and lavaged gut contents) were sent to the University of Washington for dietary analysis. Once this method of stomach contents collections was adopted, fish were only intentionally sacrificed if they were to be sent for CWT extraction and decoding.

2.3. ENVIRONMENTAL AND LOCATION DATA COLLECTION

In addition to fish data, site-specific environmental data were collected to characterize habitat and other environmental conditions. Both physical habitat and water quality data were recorded in an attempt to quantitatively and qualitatively characterize habitat conditions. Quantitative data included water temperature, ambient air temperature, location (geospatial coordinates), and tidal elevation. Qualitative data included substrate, aquatic vegetation, cloud cover, wind, and wave height.

Water temperature was collected approximately 1 m from the water's edge at approximately 0.5 m depth. Ambient air temperature was collected in the same location, approximately 0.5 m above the water's surface. Substrate type was qualitatively determined by walking along the water's edge, at the location of the set, and estimating the dominant grain size and composition. In 2002, substrate was recorded in the field as one of 10 categories: fines, mixed mud and cobble, sand, mixed sand and gravel, mixed sand and cobble, mixed sand and boulders, mixed sand with gravel and cobble, gravel, mixed gravel and cobble, and cobble. To increase the sample size for the substrate categories for statistical analyses, the substrate types were condensed into four categories: fines, sand, mixed sand, and large.

In 2001, cloud cover was described as clear, partly sunny, partly cloudy, or cloudy. In 2002, cloud cover was estimated as a percentage of the entire sky covered by clouds. Tidal height and stage were derived using "Tide Tool 2.2," tide computation software for Palm Pilot™. In 2002, wind speed and direction were estimated in knots and in cardinal directions. Presence of submerged aquatic vegetation (SAV) was recorded qualitatively in two ways. First, primary and secondary components (Zostera, Ulva, Laminarians, etc) of the attached SAV were assessed by walking the area along the beach, directly in front of the set, and taking a visual estimate of the primary and secondary components of SAV. In 2002, SAV was also qualitatively categorized as continuous, patchy, or sparse. These observations were supplemented with observations made offshore by the boat crew. Also in 2002, the presence/absence of drift (unattached) vegetation was recorded, along with the primary species component. Each set location was recorded by taking Global Positioning System (GPS) coordinates in the center of each individual sampling site.

2.4. LABORATORY ANALYSIS

2.4.1. Dietary Analysis

Lavage diet samples were sieved at 75 mm, and then wet-weighed in their entirety. Stomach samples taken from whole, preserved fish were assigned a fullness value (1=empty, 6=full) before being weighed. Prey items were identified using a dissection microscope and sorted into taxa groups, which were individually counted and weighed to the nearest 0.001 g. Small benthic and planktonic crustaceans, plus a few other taxa, were identified to species. However, for some other major prey items such as decapod larvae and insects, identification was only practicable to the order or family level. Stomach fullness was not quantified from samples obtained by gastric lavage, but all samples were assigned a digestion rank (1=no prey identifiable, 6=all prey identifiable) based upon the proportion of the sample that was identifiable.

In order to expedite comparisons among the different data groupings (e.g., size class, time period), prey items were classified into eighteen general taxonomic categories (Table 2.2). These categories were chosen to be representative of the major taxa groups present in the diet both numerically and gravimetrically (by weight) for all diet analyses. The categories needed to be general enough for yearly analyses, and specific enough to reflect changes in diet composition monthly, regionally, or by predator size class. To evaluate the food web ecology of the juvenile salmon, prey items were also categorized into one of six ecological categories (Table 2.3) (see Appendix 1 for illustrations of common prey taxa in some of these groups). These categories are not definitive for some taxa that may have planktonic phases, such as some polychaetes and amphipods. For these cases, the organism was categorized based on its primary habitat (e.g., benthic), although in many cases it was probably consumed in the water column.

During preliminary analyses for Chinook, the data were grouped into fifteen different size classes. They were then combined into six size classes based on similarity of diet composition (<90 mm, 90-109, 110-129, 130-149, 150-169, 170+). For the between-year regional and monthly size class analyses, Chinook were further combined into three size classes (<90mm, 90-149, 150+) in order to make manageable data groupings with larger sample sizes. Size classes were chosen, after examining the data, to represent changes in the diet composition. Similarly, four size classes were chosen for coho salmon diet analysis (<100 mm, 100-149, 150-199, 200+) and three for cutthroat trout (100-149 mm, 150-199, 200+).

For hatchery versus “wild” Chinook diet comparisons, those fish with clipped adipose fins or those fish with unclipped adipose fins and CWTs were assumed to be hatchery fish. Chinook without clipped adipose fins or CWTs were assumed to be “wild” fish. Only 2002 data were used for this analysis due to uncertainties of the origin of Chinook in early 2001 sampling (i.e., fewer fish checked for CWT).

Diet metrics were calculated as described by Simenstad (1991) and included percent gravimetric composition (%GC), percent numerical composition (%NC), frequency of occurrence (FO) and percent total index of relative importance (%IRI). IRI is calculated as:

$$IRI = (FO)\ (\%NC + \%GC).$$

Table 2.2. Taxa representative of general prey categories.

Prey category	Major taxa represented
Teleostei	mostly unidentifiable, sandlance (*Ammodytes hexapterus),* herring (*Clupea pallasi*)
Hyperiidea	*Hyperia spp.*, *Parathemisto spp.*
Mysid-Euphuasid-Caridea	*Holmesimysis spp., Thysanoessa raschii,* Crangonidae, Hippolytidae
Gammaridea	*Allorchestes spp., Calliopius spp., Eogammarus spp.,* Talitridae (beach hoppers)
Ostracoda	*Euphilomedes producta, E. carcharodonta*
Copepoda	*Diosaccus spinatus, Calanus spp., Epilabidocera longipedata*
Decapoda	Brachyuran zoea and megalopa, predominately *Cancer spp*.
other Crustacea	Cumacea, Caprellidea, Isopoda, Tanaidacea
Diptera	Chironomidae (midges), Sciaridae (fungus gnat), Empididae (dance fly)
Psocoptera	Psocidae (bark lice)
Hymenoptera	Formicidae (ants)
Homoptera-Hemiptera	Aphidoidea (aphids), Cicadellidae (plant hoppers)
Lepidoptera	Moths (Microlepidoptera, *Malacosoma spp.)*, lepidoptera eggs
other Insecta	Coleoptera (beetles), Isoptera (termites),
Polychaeta	*Platynereis bicanaliculata*
Other	Araneae (spiders), Acari (mites and ticks)

Table 2.3. Taxa representative of ecological categories.

Ecological category	Major taxa represented
Terrestrial riparian	adult insects and spiders
Marine planktonic/neritic	decapod larvae, hyperiid amphipods, calanoid copepods, fish larvae, barnacle exuviae
Marine benthic/epibenthic	gammarid amphipods, polychaetes, harpacticoid copepods
Supralittoral/ Marsh	Chironomid larvae and pupae, Talitridae (beach hoppers), Coelopidae (shore flies)
Plant Matter	aquatic and terrestrial plant matter

2.4.2. Coded Wire Tags

Tags were extracted from the fish, decoded (read using a binocular dissecting microscope) and recorded. Tag codes were then checked against the data stored in the Rapid Mark Information System (RMIS) database for specific release information (i.e., location, date, and size at release). The data provided by the RMIS database was then compared to our field recapture data for determination of time-at-large, distance traveled, direction of travel, and growth.

2.5. DATA AND STATISTICAL ANALYSIS

2.5.1. Analytical Steps

A stepwise process was used to summarize and analyze the survey data for temporal and spatial trends. The steps generally included for each salmonid species were:

- Step 1 – Describe the data graphically and/or statistically
- Step 2 – Evaluate the spatial and temporal distributions of salmonid composition across individual sites and regions graphically and/or statistically.

2.5.2. Descriptive Statistics

Descriptive statistics included evaluation of variable distribution as well as construction of cross-tabulated summaries of categories and record counts. Both dependent and independent variables were summarized. The primary dependent variables were catch per unit effort (CPUE), FL, and weight. Independent variables included sites, regions, sample week, and habitat or environmental variables. In addition, cross tabulations of independent variables were conducted both to illustrate patterns in the data and to evaluate correlation between variables.

CPUE was used to standardize catch data against a bias in effort over time or spatially.

$$\text{CPUE} = \text{\# of target species caught} / \text{\# of net sets}$$

Annual, weekly, daily, and instantaneous CPUEs were calculated. Data distributions of CPUE, weight, and FL were evaluated to determine if the data were normally distributed. The results of these analyses and subsequent data transformations are described below in the section on analysis methods.

2.5.3. Statistical Analyses

The methods used to test specific hypotheses depended on the type of data (categorical or continuous), and the type and level of complexity of the question. The tools used to test hypotheses, in the general order of complexity, were:

- Contingency Tables were used to analyze categorical variables to test hypotheses that the frequencies of occurrences in the categories of one variable are independent of the frequencies in the second variable.
- Analysis of Variance (ANOVA) and multiple comparisons were used to test hypotheses that the means of groups were equal.
- Simple linear regression was used to test hypotheses regarding a relationship between one or more continuous independent variables and a single continuous dependent variable.
- Analysis of Covariance (ANCOVA) combines the features of ANOVA and regression. ANCOVA was used to test hypotheses that:
    - *The means of groups were equal given the influence of a continuous independent variable*
    - *The slopes of regression lines were different for different groups*[1].

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[1] For example, were the mean lengths of hatchery or "wild" Chinook different across time? Were the intercepts or the slopes of the growth curves different for hatchery or "wild" Chinook?

As described above, descriptive statistics were run to evaluate whether data were normally distributed and whether variances were homogeneous across categories. As with most environmental data, these assumptions were generally not met. Therefore, three steps were taken to address the deviations:

1. CPUE, FL, and weight were natural-log transformed, which resulted in normally distributed data and more stable variances.

2. The Wilcoxon Rank Sums test, a nonparametric equivalent to analysis of variance (ANOVA), was used to analyze mean differences across sites, species groups, or environmental categories (Zar 1984).

3. Where parametric statistical tests were applied to the data, such as multiple comparison tests and regression analyses, the analyses were conducted using natural-log transformed data.

SECTION 3: RESULTS

3.1. *EFFORT, COMPOSITION, TIMING, DISTRIBUTION, AND SIZE*

3.1.1. Sampling Effort

Throughout the study period, 591 successful sets were made, with 290 sets in 2001, and 301 sets in 2002. A total of 28 different sites were sampled between both years. “Index” sites were designated as those where consistent repeated sampling (more than 20 sets per year) took place in both years. Seven sites met these criteria and form the basis of the data used in interannual comparisons. These sites included: Richmond Beach, Carkeek Park, Golden Gardens, Lincoln Park, Seahurst, KVI, and Maury Island Park. Picnic Point, Meadowdale, Ocean Avenue, and Burton sites each had more than 20 sets in 2001 only. Sampling took place between 0800 and 2400 hours, the bulk of which (98%) took place between 0900 and 1800 hours. Sampling occurred from May 15 through October 11 and from April 17 to December 9 in 2001 and 2002, respectively (Table 3.1).

Table 3-1. Summary of successful sets made during the study by site (* = Index Sites) and region.

		April	May		June		July		Aug		Sept		Oct		Dec	Total	Total	
		02	01	02	01	02	01	02	01	02	01	02	01	02	02	01	02	Totals
WRIA 8 (North)	Picnic Point	6	6	8	4	0	4	0	5	0	4	0	2	0	0	25	14	39
	Meadowdale	4	6	8	4	0	4	0	4	0	4	0	2	0	0	24	12	36
	Ocean Ave	0	6	0	4	0	4	0	4	0	4	0	2	0	0	24	0	24
	Deer Creek	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	Edmonds	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	4	4
	*Richmond Beach	3	6	9	4	4	4	5	3	5	4	6	1	6	0	22	38	60
	*Carkeek	0	6	2	4	4	4	4	4	4	4	4	2	4	0	24	22	46
	*Golden Gardens	0	3	2	4	6	4	7	4	4	4	6	2	4	1	21	30	51
WRIA 9 (South)	*Lincoln Beach	0	3	2	7	4	4	6	4	4	4	6	2	5	1	24	28	52
	*Seahurst Park	0	3	2	8	4	4	6	5	4	4	6	1	4	3	25	29	54
	Marine View	0	3	0	4	0	4	0	4	0	4	0	2	0	0	21	0	21
WRIA 9 (Vashon/Maury Islands)	*KVI	0	6	2	4	4	4	4	5	4	4	5	6	5	0	29	24	53
	*Maury Island Park	0	6	2	4	4	4	4	4	4	4	4	7	4	0	29	22	51
	Burton	0	3	2	4	2	4	0	4	0	4	1	2	0	0	21	5	26
	Tramp Harbor	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1
	DNR Beach 83	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	3	3
	Point Robinson	0	0	0	0	0	0	0	0	1	0	3	0	7	0	0	11	11
	Camp Sealth	0	0	0	0	0	0	2	0	2	0	2	0	2	0	0	8	8
	Talequah/KLP 1	0	0	5	0	0	0	0	0	1	0	0	0	0	0	0	6	6
	KLP 2	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	5	5
	EEG 1	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	5	5
	EEG 2	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	6	6
	MD 1	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	4	4
	MD 2	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	4	4
	SGB 1	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	5	5
	SBG 2	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	5	5
	SGF 1	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	5	5
	SGF2	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	5	5
	Totals	15	57	91	55	34	49	39	50	33	48	43	31	41	5	290	301	591

3.1.2. Salmonid Catch Summary

A total of 122,810 individual fish were caught during the two-year study period (Appendix 2). Of these, 33,993 represented nine species of salmonids (Table 3.2). Chum were the most abundant salmonid captured (27,296), followed by pink (2,518), Chinook (2,420), coho (1,287), cutthroat trout (344), sockeye (117), steelhead (9), bull trout (1), and Atlantic salmon (1). Percent frequency of occurrence of salmonids in 2001 and 2002 is presented in Table 3.3. Chinook occurred in the catch at almost the same frequency within and between years. Coho frequency of occurrence in 2001 was less than 2002, primarily due to higher catch occurrences in May and August of 2002. Chum frequency of occurrence was also higher in 2002 and tended to peak in April/May. Pinks only occurred in April and May of 2002. The frequency of cutthroat occurrence showed variability within a given year, but not between years. Neither sockeye nor steelhead occurred in great frequency, and sockeye were caught only in the months of June and July in both years.

Table 3-2. Total number of salmonids caught by year.

Species	2002 totals	2001 totals	Sum totals
Chum	24,740	2,556	27,296
Pink Salmon	2,518	0	2,518
Chinook	1,354	1,066	2,420
Coho	1,053	234	1,287
Cutthroat	133	211	344
Sockeye	4	113	117
Steelhead	2	7	9
Char	1	0	1
Atlantic Salmon	0	1	1
Salmonid totals	29,805	4,188	33,993

Table 3.3. Percent frequency of occurrence of salmonids by month for 2001 and 2002.

	2001						
Species	May	June	July	Aug	Sept	Oct	Total
Clipped Chinook	42.11%	49.09%	55.10%	48.00%	33.33%	22.58%	43.10%
Unclipped Chinook	29.82%	58.18%	44.90%	52.00%	22.92%	19.35%	39.31%
Clipped Coho	7.02%	23.64%	18.37%	2.00%	0.00%	0.00%	9.31%
Unclipped Coho	14.04%	47.27%	22.45%	2.00%	10.42%	3.23%	17.93%
Chum	82.46%	34.55%	12.24%	14.00%	2.08%	9.68%	28.62%
Pink	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cutthroat	17.54%	36.36%	28.57%	12.00%	20.83%	16.13%	22.41%
Sockeye	0.00%	9.09%	10.20%	0.00%	0.00%	0.00%	3.45%
Steelhead	7.02%	3.64%	0.00%	2.00%	0.00%	0.00%	2.41%

	2002								
Species	April	May	June	July	Aug	Sept	Oct	Dec	Total
Clipped Chinook	6.67%	39.56%	76.47%	58.97%	60.61%	30.23%	7.32%	0.00%	41.21%
Unclipped Chinook	0.00%	16.48%	58.82%	46.15%	48.48%	46.51%	29.27%	20.00%	34.46%
Chinook (unknown clip)	0.00%	2.20%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.68%
Clipped Coho	0.00%	35.16%	23.53%	17.95%	12.12%	4.65%	0.00%	0.00%	17.91%
Unclipped Coho	0.00%	38.46%	47.06%	28.21%	15.15%	0.00%	0.00%	0.00%	22.64%
Coho (unknown clip)	0.00%	2.20%	2.94%	0.00%	3.03%	0.00%	0.00%	0.00%	1.35%
Chum	100.00%	87.91%	73.53%	30.77%	18.18%	0.00%	0.00%	0.00%	46.62%
Pink	80.00%	14.29%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	8.45%
Cutthroat	6.67%	26.37%	32.35%	15.38%	30.30%	11.63%	12.20%	0.00%	20.95%
Sockeye	0.00%	0.00%	2.94%	0.00%	0.00%	0.00%	0.00%	0.00%	0.34%
Steelhead	0.00%	1.10%	0.00%	2.56%	0.00%	0.00%	0.00%	0.00%	0.68%

3.1.3. Proportions of Marked and Unmarked fish

Marked and unmarked Chinook and coho salmon captured in this study were used to identify the relative hatchery and "wild" proportions of these salmonids. Equipment to detect CWTs was not available early in 2001, limiting the ability to identify hatchery origin fish by adipose fin clipping alone. Chinook and coho were placed into three categories: hatchery, "wild" and unknown (not clipped/unknown CWT). It should be noted that some portion of fish categorized as "wild" were also likely of hatchery origin, due to the fact that not all of hatchery released fish are marked in some manner (fin clip and/or CWT). No PIT tags were detected during the study.

3.1.3.1. Chinook

Of the 770 Chinook measured (FL) in 2001, 415 were of known hatchery origin (fin clipped and/or CWT = "hatchery"), 225 unmarked ("wild"), and 128 unknown (not clipped/unknown CWT) (Table 3.4). In 2002, 1,285 Chinook were measured of which 963 were hatchery and 322 "wild" (Table 3.5). In 2001, the total proportions of hatchery, "wild," and unknown Chinook were 54%, 29%, and 17%, respectively. In 2002, the total proportions of hatchery and "wild" Chinook were 75% and 25%, respectively.

Table 3.4. Summary of clipped, unclipped and CWT Chinook and coho by site in 2001.

	2001 Totals per site											
	Clipped Chinook			Unclipped Chinook			Clipped Coho			Unclipped Coho		
	CWT	Non CWT	Ukn CWT	CWT	Non CWT	Ukn CWT	CWT	Non CWT	Ukn CWT	CWT	Non CWT	Ukn CWT
Richmond Beach	4	10	11	1	12	15	0	1	3	0	0	19
Carkeek Park	6	26	2	3	15	3	0	4	0	0	5	3
Golden Gardens	3	14	3	2	6	1	0	1	1	0	2	8
Lincoln Beach	17	22	39	14	45	72	0	4	1	0	3	2
Seahurst Park	8	31	7	5	28	6	0	5	7	0	12	4
KVI	5	12	4	2	23	1	0	1	0	0	1	3
Maury Island Park	4	31	5	3	46	1	0	0	1	3	8	0
Burton	6	25	0	1	9	0	0	0	0	0	0	0
Marine View	8	19	1	3	28	0	0	0	1	1	5	3
Meadowdale	10	15	2	2	6	14	0	0	0	1	4	7
Oceanview	3	6	7	0	3	12	1	0	0	0	0	3
Picnic Point	7	4	0	1	4	3	0	0	4	0	6	11
Tramp Harbor	0	1	0	0	0	0	0	0	0	0	0	0
Totals	81	216	81	37	225	128	1	16	18	5	46	63
	415				225	128	40				46	63
	54.04% Marked				29.30% Unmarked	16.67% Unknown	26.85% Marked				30.87% Unmarked	42.28% Unknown

In each month of 2001, hatchery Chinook salmon were found in higher numbers than "wild", with the exception of October when they were roughly equivalent (Figure 3.1). The relative proportions of hatchery and "wild" Chinook varied by month in each year. Note, however, that the unknown category represents a large proportion of the catch early in the sampling season and some portion of the unknown group would contribute to each category. In 2002, the monthly proportions of hatchery and "wild" Chinook also varied by month. Hatchery Chinook exceeded "wild" Chinook catches in May (88%), June (82%) and July (73%), but were found less frequently than "wild" Chinook in August (40%), September (41%) and October (29%) (Figure 3.2).

Table 3.5. Summary of clipped, unclipped and CWT chinook and coho, by site in 2002.

	2002 Totals per site							
	Clipped Chinook		Unclipped Chinook		clipped Coho		Unclipped Coho	
	CWT	Non CWT	CWT	non CWT	CWT	Non CWT	CWT	Non CWT
Richmond Beach	15	106	24	88	5	12	0	71
Carkeek Park	5	16	11	16	2	5	2	14
Golden Gardens	7	49	7	24	2	4	0	24
Lincoln Beach	13	142	18	72	2	10	0	49
Seahurst Park	2	12	2	19	0	6	0	3
KVI	9	57	6	26	0	0	0	2
DNR Beach 83	4	134	7	8	0	0	0	0
Pt. Robinson	4	11	3	19	0	1	0	0
Maury Island Park	2	71	1	12	1	20	0	11
Burton	0	2	0	0	0	1	0	0
Talequah Point	0	1	0	0	0	0	0	0
Camp Sealth	1	8	0	6	0	1	0	1
EEG1	0	1	0	0	0	0	0	0
EEG2	0	4	0	0	1	60	2	3
SGB1	0	1	0	0	0	2	0	2
SGB2	0	16	0	1	1	10	0	7
Mud1	0	0	0	1	0	0	0	0
Mud2	0	0	0	0	0	0	0	1
SGF1	0	23	0	1	0	1	0	3
SGF2	1	2	0	0	0	0	0	0
KLP1	6	141	2	11	1	52	3	15
KLP2	0	4	0	0	0	0	0	2
Deer Creek	0	0	0	1	5	5	0	12
Edmonds	0	0	0	1	0	0	0	0
Picnic Point	3	0	1	11	4	13	5	60
Meadowdale	4	3	1	5	9	24	4	50
totals	76	804	83	322	33	227	16	330
	880		405		260		346	
	1285				606			
	963			322	276			330
	74.94% Hatchery			25.06% "wild"	45.54% Hatchery			54.46% "Wild"

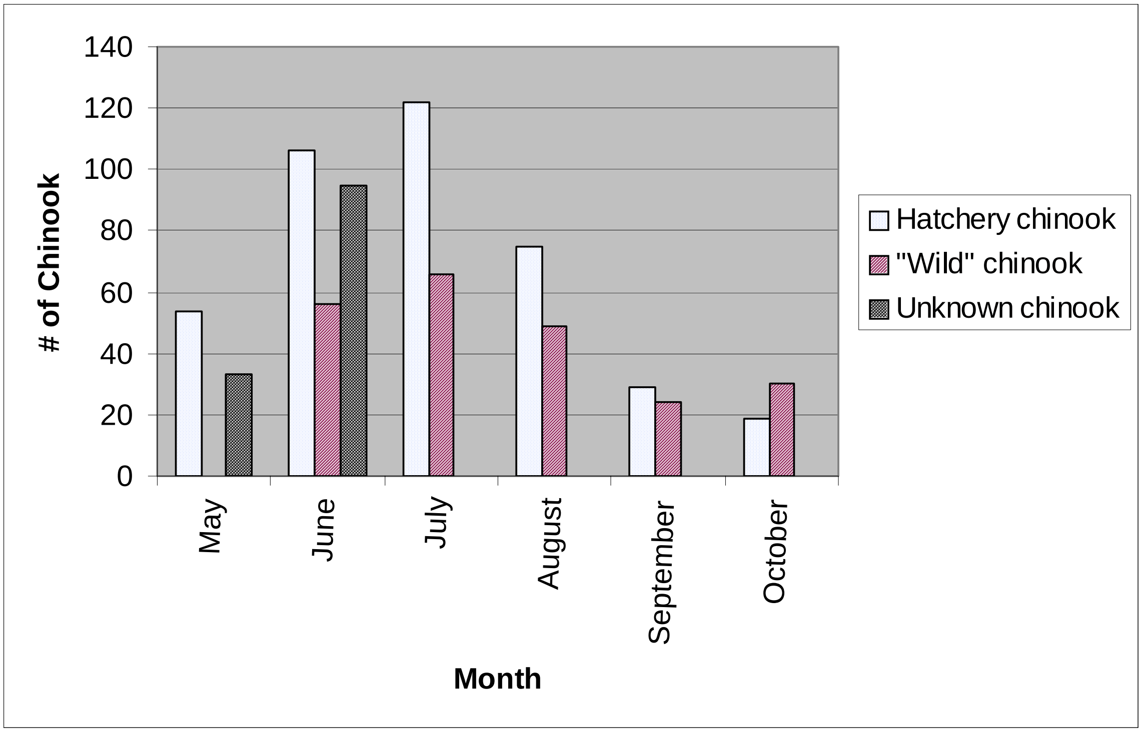


Figure 3.1. Number of hatchery and "wild" Chinook caught by month in 2001

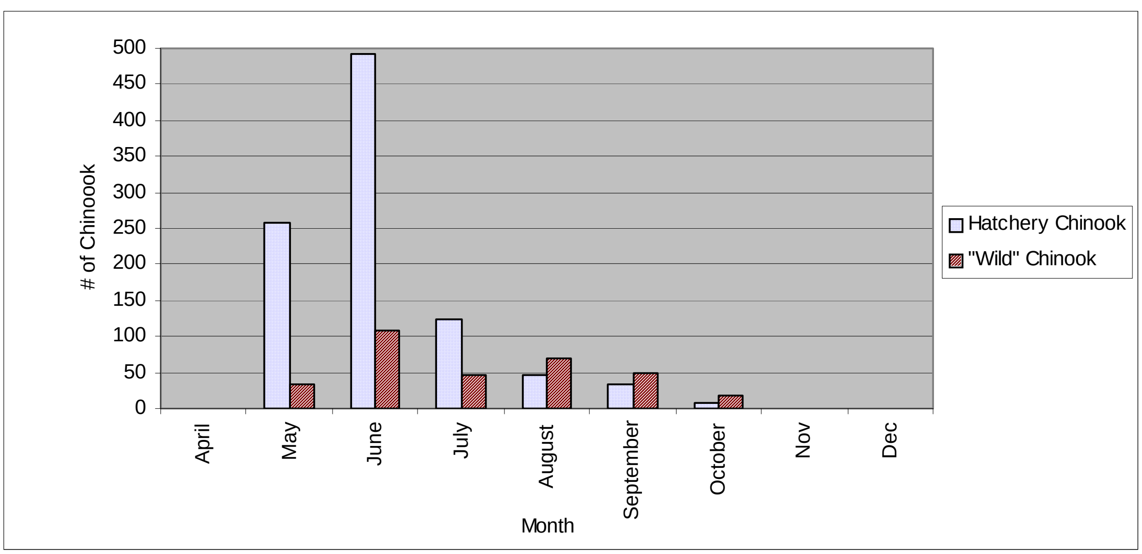


Figure 3.2. Number of hatchery and "wild" Chinook caught by month in 2002.

3.1.3.2. Coho

Of the 149 measured coho caught in 2001, 40 were marked, 46 unmarked, and 63 were of unknown origin (Table 3.4). The total proportions of hatchery, “wild,” and unknown coho were 27%, 31%, and 42%, respectively. In 2002, 606 coho were measured of which 276 were hatchery and 330 “wild” (Table 3.5). The total proportions of hatchery and “wild” coho were 46% and 54%, respectively.

In 2001, “wild” coho appeared to exceed the catch of hatchery coho for all months, except June (Figure 3.3). However, in 2001, coho were checked less frequently than Chinook for CWTs, which resulted in a lower level of classification certainty. In addition, the marking of hatchery coho occurs at a lower rate than marking of hatchery Chinook (refer to rmis.org & wdfw.wa.gov). In 2002, hatchery coho catch was less than “wild” coho in June (9%), July (46%), and August (41%), but exceeded the “wild” coho catch in May (54%) (Figure 3.4).

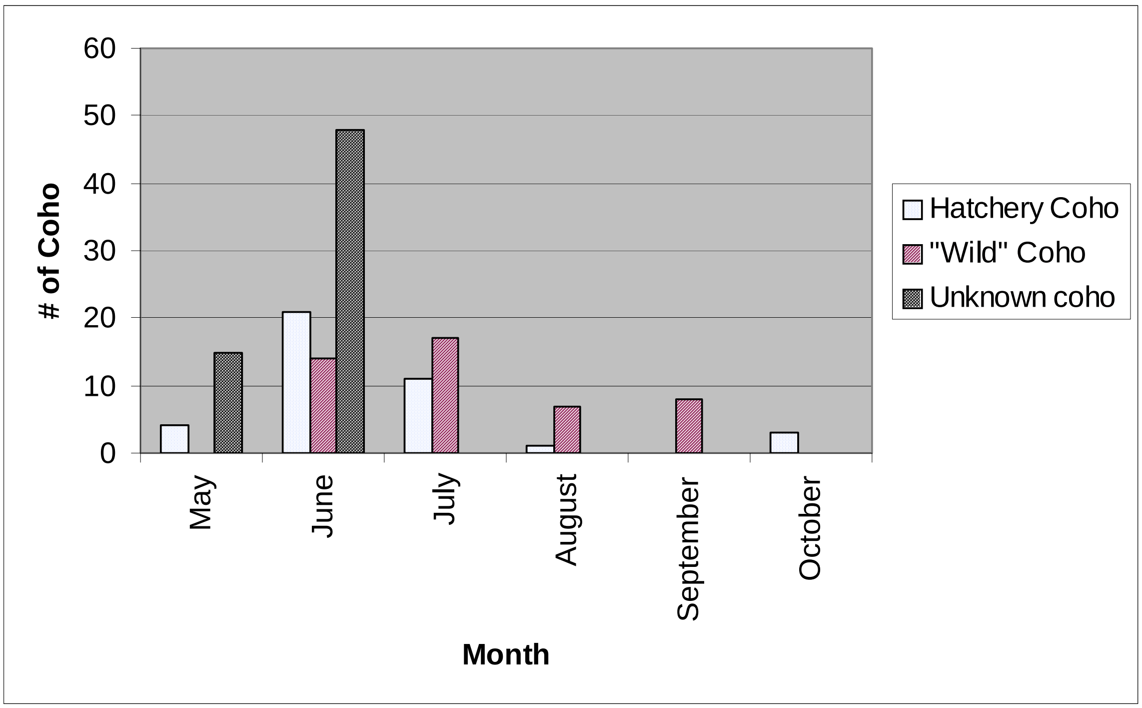


Figure 3.3. Number of hatchery and “wild” coho caught by month in 2001.

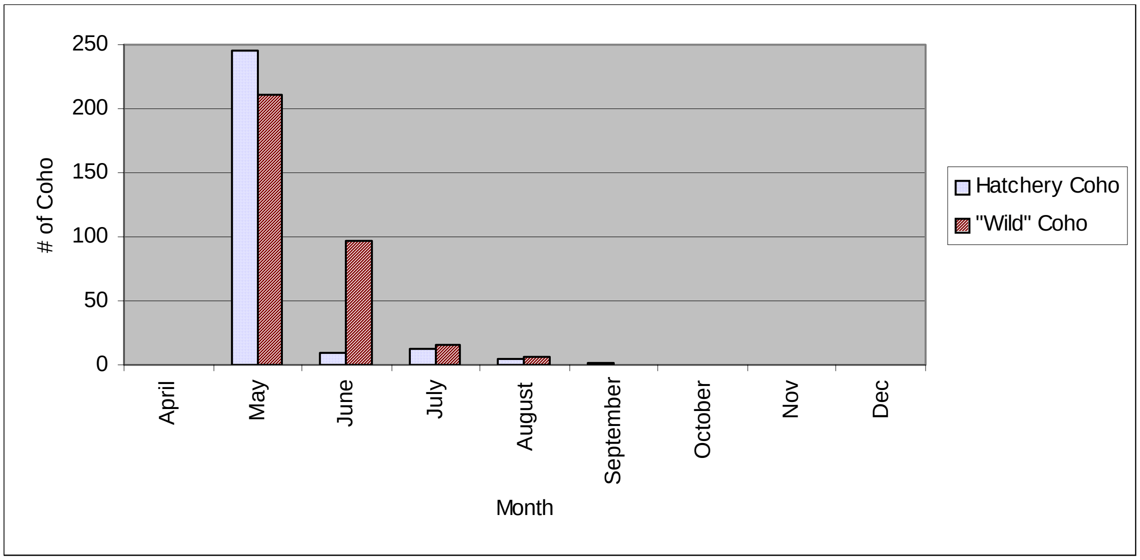


Figure 3.4. 2002 Clipped, Unclipped, and CWT coho.

3.1.4. Temporal Catch Patterns

Temporal patterns were analyzed using the total catch data for the main salmonid species caught throughout the study period for all salmon (except sockeye) and cutthroat trout. Due to low catches, sockeye, steelhead, Atlantic salmon, and char were not included in this analysis. Since the total catch data were used for these analyses, and not the detailed subsample of measured fish, some of the unclipped fish were actually hatchery fish due to CWT recoveries of unclipped fish. This may bias some of the analyses by not including CWT fish in estimates of hatchery fish for these analyses.

Patterns in CWT recoveries (see below) and information from Duffy (2003) indicate differences in the distribution of hatchery and wild Chinook in Puget Sound. Therefore, temporal patterns of CPUE were analyzed for three regions within the study area: north mainland (WRIA 8), south mainland (WRIA 9), and Vashon/Maury Islands (WRIA 9). The weekly CPUE for all sites within those regions for 2001 and for 2002 were combined and plotted over time by sample week (Figures 3.5, 3.6, and 3.7). Standard errors associated with Figures 3.5 through 3.7 and salmonid weekly CPUE for each of our index sites plotted over time can be found in Appendix 3. Peaks in CPUE were variable for all species and for both years. Comparing the primary peak and secondary peaks in CPUE for all three regions in both years reveals some patterns for different regions and species (Table 3.6).

Table 3.6. The week of primary and secondary peaks of CPUE of Chinook, coho, chum, cutthroat, and pink by region.

	2001 Unclipped Chinook		2001 Clipped Chinook		2002 Unclipped Chinook		2002 Clipped Chinook	
	1º peak	2º peak	1º peak	2º peak	1º peak	2º peak	1º peak	2º peak
North Mainland	June 11th	May 15th	July 23rd	May 29th	June 17th	Aug 12th	June 17th	Aug 12th
South Mainland	June 1st	July 23rd	June 11th	July 23rd	July 22nd	June 17th	June 17th	July 15th
Vashon/Maury	July 23rd	June 11th	July 23rd	June 11th	June 17th	Aug 12th	June 17th	Aug 12th

	2001 Chum	2002 Chum	2001 Cutthroat		2002 Cutthroat		2002 Pink
	1º peak	1º peak	1º peak	2º peak	1º peak	2º peak	1º peak
North Mainland	June 1st	May 13th	Oct 8th	June 25th	May 20th	May 10th	April 23rd
South Mainland	June 1st	May 20th	Oct 8th	June 25th	June 17th and Aug 5th	no peak	no peak
Vashon/Maury	June 1st	May 29th	June 11th	no peak	July 22nd	no peak	no peak

	2001 Unclipped coho		2001 Clipped coho		2002 Unclipped coho		2002 Clipped coho	
	1º peak	2º peak	1º peak	2º peak	1º peak	2º peak	1º peak	2º peak
North Mainland	June 25th	May 29th	June 25th	July 23rd	May 20th	June 17th	May 13th	no peak
South Mainland	June 25th	May 29th	May 15th	June 11th	May 20th	June 17th	May 20th	no peak
Vashon/Maury	Aug 27th	June 11th	no peak	no peak	May 13th	May 20th	May 13th	May 20th

3.1.4.1. Chinook

Peak catch rates of juvenile Chinook (Figures 3.5a; 3.6a; 3.7a), both clipped and unclipped, varied considerably between regions and between years. In both years, multiple peaks in CPUE were observed. In 2001, there was a general pattern for clipped and unclipped Chinook of peak catches moving from south to north. CPUE of clipped and unclipped Chinook peaked at south mainland sites in early June. Vashon/Maury sites peak CPUE occurred in late July. North mainland sites CPUE peaked in mid-June for unclipped Chinook and in late July for clipped Chinook.

In 2002, clipped and unclipped Chinook peaked at the north mainland sites and the Vashon/Maury sites in mid-June, with a secondary peak in mid-August. At south mainland sites, clipped and unclipped Chinook showed almost opposite patterns in relation to each other. Clipped fish peaked in mid-June, followed by a secondary peak in mid-July, while unclipped Chinook peaked in mid-July, preceded by a secondary peak in mid-June.

3.1.4.2. Coho

Peak CPUE in 2001 of clipped coho (Figures 3.5b; 3.6b; 3.7b) occurred in mid-May during the first week of sampling at the south mainland sites. Unclipped coho peaked in mid-June. The north mainland sites had a primary peak CPUE in late June and a secondary peak in late May for unclipped coho. Peak CPUE for clipped coho at northern sites occurred in late June, with a secondary peak in late July.

In 2002, the CPUE of coho peaked in the first week of sampling (mid-May) at the south mainland and Vashon/Maury sites. The timing of peak CPUE for unclipped coho at the northern sites were reversed in relation to 2001, with the primary peak occurring mid-May and the secondary peak occurring mid-June. The peak weekly CPUE of clipped coho at north mainland sites was similar to that of unclipped coho in both years. There was only one distinct peak for clipped coho in 2002, mid-May.

Since the peak of weekly CPUE at the south mainland and Vashon/Maury regions occurred in the first week of sampling in both sampling years, it appears that this study likely missed the primary peak in CPUE of both clipped and unclipped coho in these regions. Daily CPUE for clipped and unclipped coho were significantly higher in 2002 than in 2001 (Wilcoxon test; $p<0.05$).

3.1.4.3. Chum

Chum weekly CPUE (Figures 3.5c; 3.6c; 3.7c) peaked in early June in all regions in 2001. In 2002, the peak occurred earlier (late May) and progressed from north to south. Daily CPUE for chum were significantly higher in 2002 than in 2001 (Wilcoxon test; $p<0.05$).

3.1.4.4. Pink

No pinks were seen during sampling in 2001 as predicted. However, in 2002 pinks were almost entirely absent from WRIA 9 mainland and Vashon/Maury sites, only being caught on one day. At the north mainland sites, pinks peaked early in 2002 sampling, in mid/late April (Figure 3.5d).

3.1.4.5. Cutthroat

Cutthroat trout were caught in small numbers throughout the sample period, making a summary of peak CPUE patterns difficult (Figures 3.5e; 3.6d; 3.7d). However, in 2001, both mainland regions had a primary peak in weekly CPUE in early October and a secondary peak in late June. Vashon/Maury sites had a small peak during the week of June 11. In 2002, north mainland CPUE peaked early in the sample season with primary and secondary peaks in late and early May, respectively. South mainland sites had two equal peaks in mid-June and early August and Vashon/Maury sites peaked in late July.

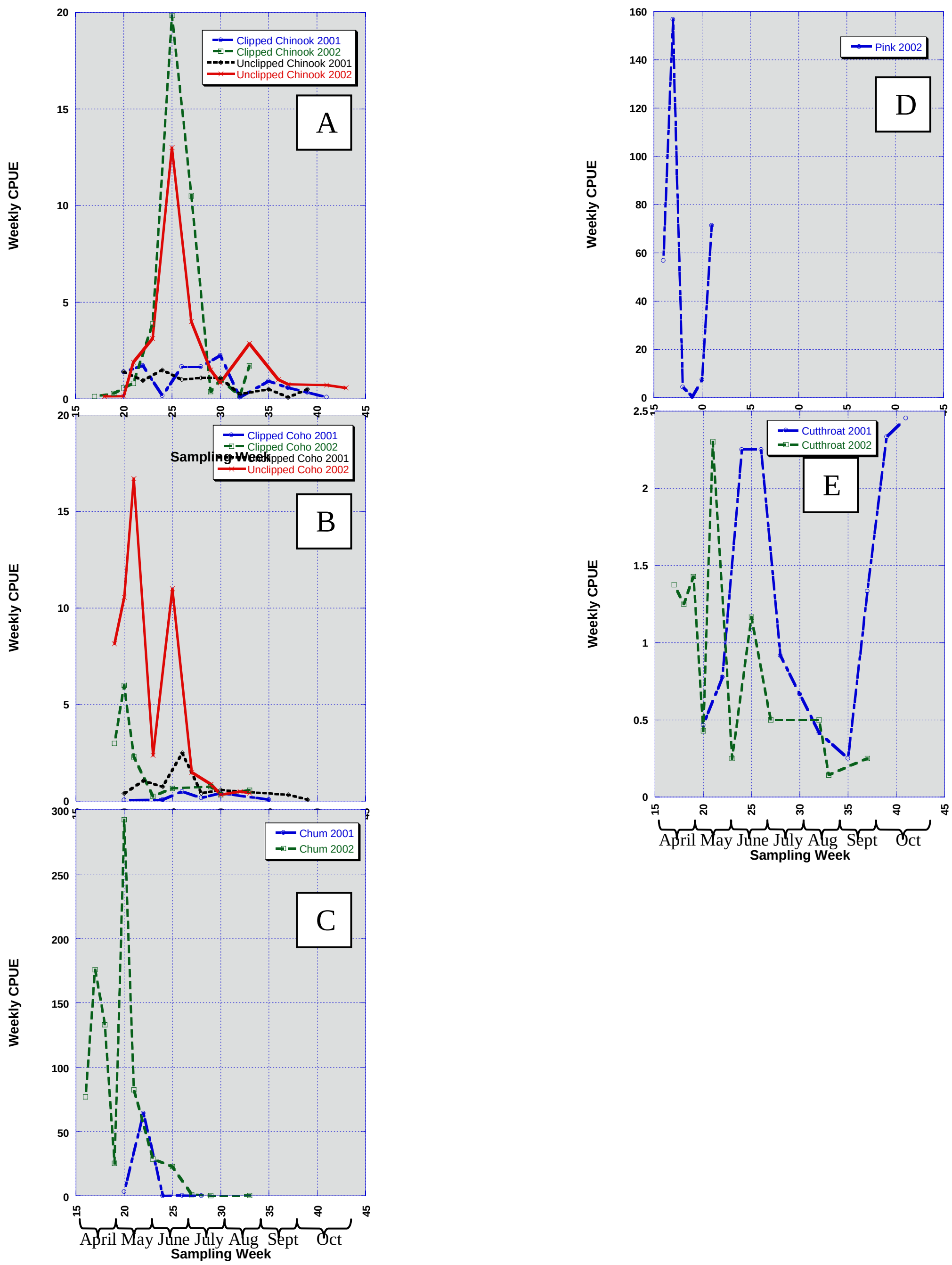


Figure 3.5. Combined CPUE for north mainland sample sites (WRIA8) by sample week for a) clipped and unclipped Chinook and b) coho, c) chum, d) pink and e) cutthroat in 2001 and 2002 (Note the change in weekly CPUE scale between plots).

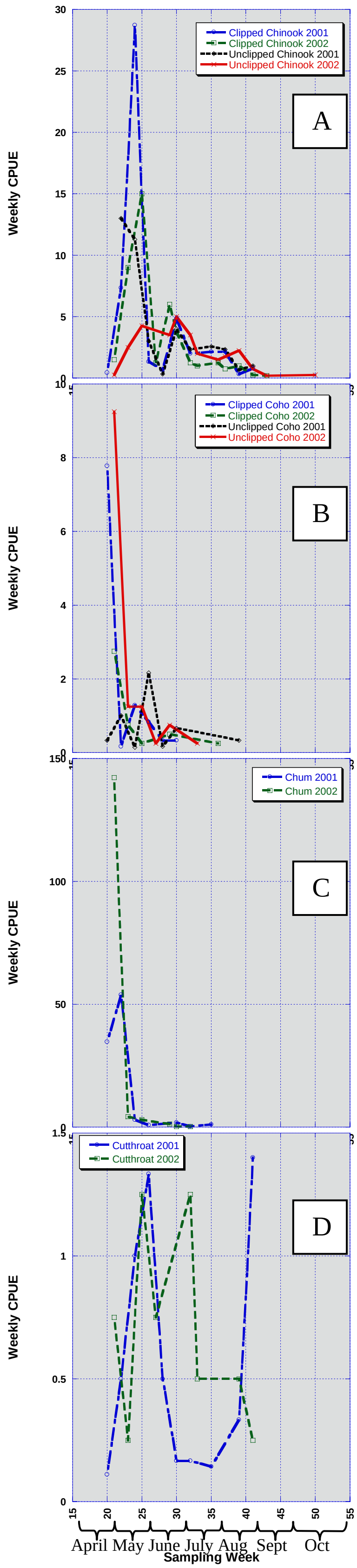


Figure 3.6. Combined CPUE for south mainland sample sites (WRIA 9) by sample week for a) clipped and unclipped Chinook and b) coho, c) chum and d) cutthroat in 2001 and 2002.
(Note the change in weekly CPUE scale between plots).

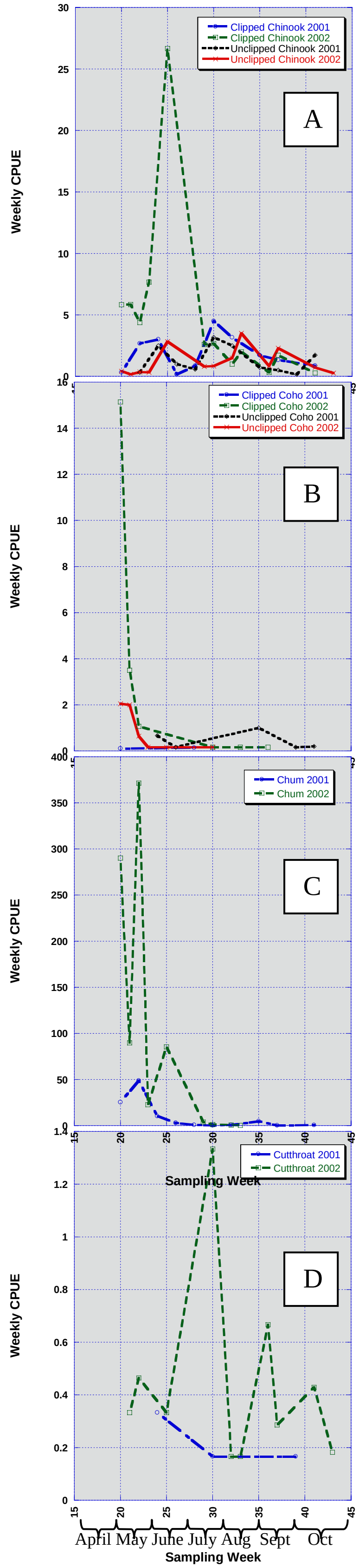


Figure 3.7. Combined CPUE for Vashon/Maury Island sample sites (WRIA 9) by sample week for a) clipped and unclipped Chinook and b) coho, c) chum and d) cutthroat in 2001 and 2002
(Note the change in weekly CPUE scale between plots).

1.1 Spatial Catch Patterns

Spatial patterns for both years were analyzed using the total catch data for the main salmonid species caught throughout the study period, including Chinook, coho, chum, and cutthroat. Pinks were analyzed only for 2002 since none were caught in 2001. Statistical comparisons were made with calculated daily CPUE values between the 3 regions of the study area (e.g. north, south, and island) within years Graphic comparisons were made with calculated annual CPUE between regions (Figure 3.8) within and between years.

3.1.5.1. Chinook

In 2001, both clipped and unclipped Chinook CPUE was highest at south mainland sites and lowest at north mainland sites (Figure 3.8). Daily CPUE of unclipped Chinook in 2001 at the south mainland sites was significantly higher than the other two regions (Wilcoxon test, $p<0.05$). In 2002, the CPUE of clipped Chinook appeared highest at the Vashon/Maury sites, while the CPUE of unclipped Chinook appeared highest at south mainland sites (Figure 3.8). However, statistically, there was no significant difference in the CPUE of clipped and unclipped Chinook between the 3 regions in 2002. The CPUE of clipped and unclipped Chinook did not show any discernable patterns between years.

3.1.5.2. Coho

For each year, the unclipped coho annual CPUE appeared highest at the north mainland sites and lowest at the Vashon/Maury sites (Figure 3.8). The CPUE of clipped coho did not show any discernable patterns between years, and there were no significant differences within years for either clipped or unclipped coho (Wilcoxon test, $p>0.05$).

3.1.5.3. Chum

The CPUE of chum appeared to be higher in 2002 than in 2001 at the north mainland and island sites than (Figure 3.8). Statistically, there were no significant differences within years.

3.1.5.4. Pink

Juvenile pinks are dominant in even years relative to odd years within the study area. In 2002, the highest annual CPUE of pink salmon occurred in the north mainland region, with a very low annual CPUE at Vashon/Maury region and with no pinks being caught in the south mainland region (Figure 3.8). While the difference in pink daily CPUE was not significantly different (Wilcoxon test, $p>0.05$), that is most likely due to the large variance involved with the low catches in the other two regions.

3.1.5.5. Cutthroat

In both years, cutthroat annual CPUE was highest at the north mainland sites and lowest at the Vashon/Maury sites (Figure 3.8). Statistically, CPUE was significantly higher at the north mainland sites than at south mainland sites in 2001 only (Wilcoxon test, $p<0.05$).

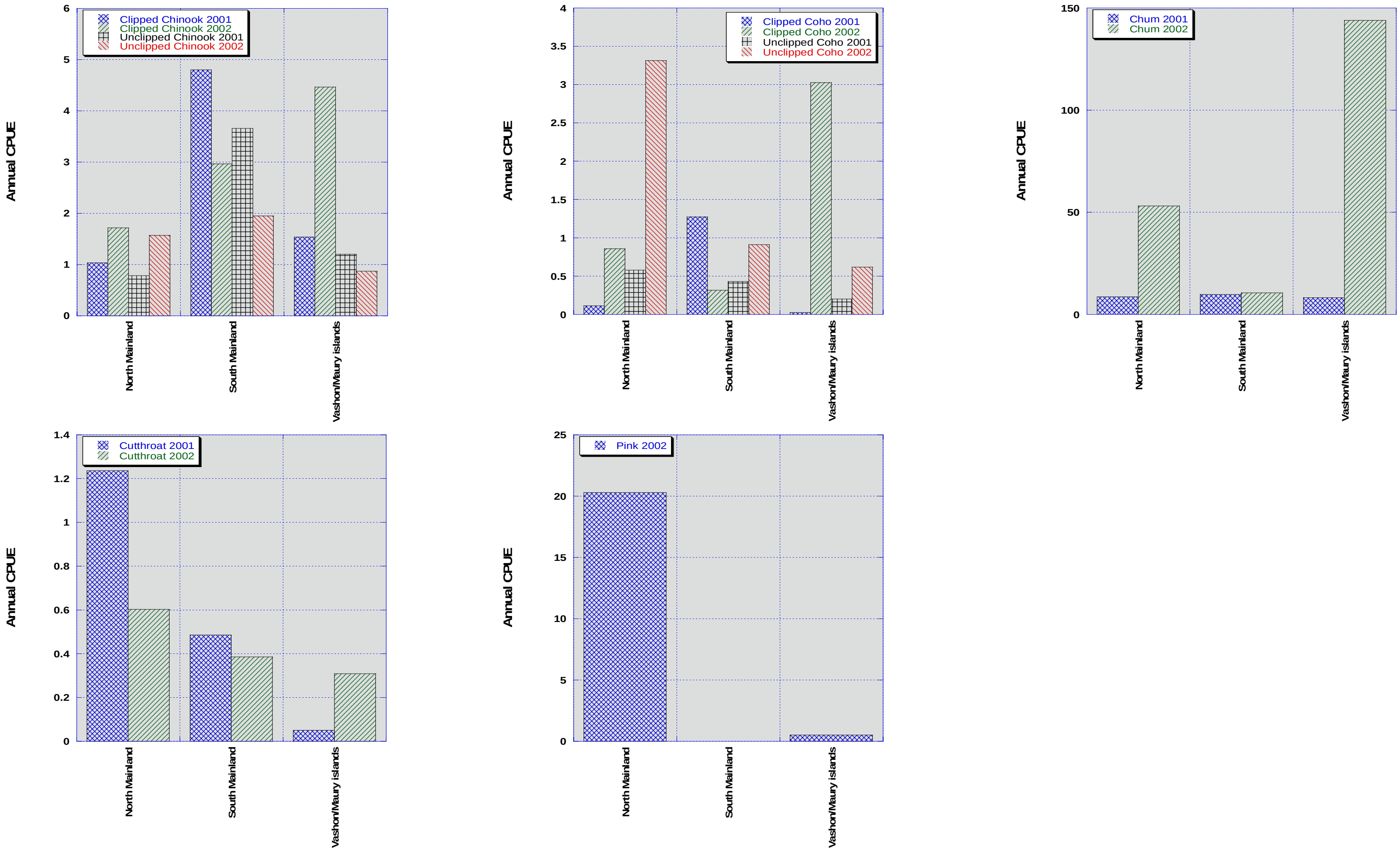


Figure 3.8. Annual CPUE by regions in 2001 and 2002, for Chinook, coho, chum, pink, and cutthroat.

3.1.5.2. Frequently Sampled Sites

Salmonid annual CPUE for the index sites was plotted for each year (Figure 3.9). For statistical comparisons, the daily CPUE was used. As can be seen graphically, Lincoln Beach had the highest annual CPUE for clipped and unclipped Chinook in both 2001 and 2002. Statistical analysis of daily CPUE of Chinook indicated that in 2001 the CPUE of Chinook was not significantly different between sites. There was a difference between all sites in 2002 (Wilcoxon test; $p>0.1$). In 2002, Lincoln Beach had significantly higher CPUE than only one site, Seahurst Park. The graphical observation was confirmed by a t-test between individual pairs of sites, ($p<0.05$).

The highest annual CPUE in 2001 for unclipped coho was found at Richmond Beach, while clipped coho were most abundant at the Seahurst Park site. In 2002, Richmond Beach and Lincoln Beach had similarly high CPUE for unclipped coho. For clipped coho, Maury Island Marine Park had the highest annual CPUE.

In both years the highest yearly CPUE for chum was at Richmond Beach. In 2002, Richmond Beach also had the highest yearly CPUE for pink salmon. Interestingly, the CPUE for pink salmon declined from north to south. Cutthroat trout yearly CPUE was highest at Seahurst Park in both 2001 and 2002.

3.1.6. Environmental and Catch Relationships

Most of the sample locations for the study were selected based on logistical constraints and the study was not designed to explicitly test the relationships between substrate, vegetation, and fish abundance or distribution. While analyses can be conducted using the available dataset to describe these relationships and better understand possible causes for the observed distribution of fish, cause cannot be directly inferred.

The methods for the collection of environmental data varied throughout the study area in both years. Several variables were not collected in a consistent manner in 2001 or between years. Therefore, only 2002 data were used in our analyses evaluating the relationship between substrate type, presence and type of submerged aquatic vegetation, presence/absence of drift vegetation, and percent cloud cover to CPUE of salmonids. Temperature, tides (tide height and stage), and time of day were all collected/recorded in a consistent manner between both years.

3.1.6.1. Environmental Data Summary

In 2002, the percentages of sets made in each substrate category are fines (3.0%), sand (20%), mixed sand (42%), and large (34%) (Table 3.7). Various species of submerged aquatic vegetation (SAV) were recorded as the primary component and secondary component of attached SAV present, or as drift. Ulva and Zoestera were the most abundant attached primary SAV types, being present in 29% and 39% of the sets, respectively (Table 3.8). Approximately, 28% of the sets were not associated with any attached SAV. Presence or absence, and the primary component of drift vegetation, was recorded for 286 sets out of 301 sets made in 2002. Drift vegetation was present at 63% of sets in 2002.

Since this study did not focus on tidal effects, the continuous tide variable was combined into the following categories: <0, 0 to +3, +3 to +6, and >+6 feet (Table 3.9). For both years, the dominant (50%) tide height during sampling was greater than a +6 tide elevation. Another variable recorded was the tidal stage (ebb, flood, slack). For both years, 46% of the sets were made during ebb tides, 36% were sets were made during flood tides, and 17% of the sets were made at slack tides (Table 3.10).

Water temperature was collected for 552 sets. The range of temperatures experienced during the two years was from 5ºC to 20ºC (Table 3.11). Almost 70% of the sets occurred in water from 12-14º C.

Because of the limited range of water temperature and its correlation with the time of the year, the relationship with catch was not evaluated.

Cloud cover data were collected differently and somewhat inconsistently for both years. To illustrate the cloud cover observed over the study period, the cloud cover data were combined to the categories described in Table 3.12. Because of the inconsistency in cloud cover records and the correlation with the time of the year, the relationship with catch was not evaluated.

Table 3.7. Substrate distribution for sets made in 2002.

Primary SAV Taxa	Frequency of Occurrence	Percent of Total
Zostera	118	39.20%
Ulva	86	28.57%
Other	14	4.69%
None	83	27.57%
Secondary SAV Taxa		
Zostera	26	8.64%
Ulva	61	20.27%
Other	30	10.00%
None	184	61.13%

Table 3.8. Frequency of occurrence of attached SAV in 2002 where presence/absence of SAV was recorded as either being the primary or secondary component.

Recorded as	Combined to	% composition
Fines	Fine	3.00%
Mixed Mud and Cobble		
Sand	Sand	19.60%
Mixed Sand and Gravel	Mixed Sand	42.20%
Mixed Sand and Cobble		
Mixed Sand and Boulders		
Mixed Sand, Gravel and Cobble		
Gravel	Large	34.20%
Mixed Gravel and Cobble		
Cobble		

Table 3.9. Number and percent of sets made by tide heights.

Tide Height	<0	0 to +3	+3 to +6	>+6	Total # Sets
2001	10	57	60	163	290
2002	47	50	73	131	301
Total	57	107	133	294	591
%	9.64%	18.10%	22.50%	49.75%	

Table 3.10. Number and percent of sets made by tidal stage in 2001 and 2002.

Tidal Stage	Ebb	Flood	Slack	Total # of Sets
2001	159	117	14	290
2002	114	98	89	301
Total	273	215	103	591
%	46.19%	36.38%	17.43%	

Table 3.11. Frequency of occurrence of water temperature by set in 2001 and 2002.

	Frequency of Occurrence		Total	%
Temp ºC	2001	2002	Occurrence	Occurrence
5	0	2	2	0.36%
6	0	1	1	0.18%
7	0	0	0	0.00%
8	0	3	3	0.54%
9	0	7	7	1.27%
10	5	12	17	3.08%
11	17	24	41	7.43%
12	69	33	102	18.48%
13	99	69	168	30.43%
14	44	62	106	19.20%
15	15	38	53	9.60%
16	6	17	23	4.17%
17	10	7	17	3.08%
18	2	4	6	1.09%
19	0	2	2	0.36%
20	2	2	4	0.72%

Table 3.12. Frequency of occurrence of cloud cover categories by set for 2001 and 2002.

2001 Cloud Cover Designation	2002 Cloud Cover %	# of Sets in 2001	# of Sets in 2002	Frequency of Occurrence	% of Occurrence
Clear	0	80	41	121	25.00%
Mostly Sunny	1-19	7	40	47	9.71%
Partly Cloudy	20-50	37	80	117	24.17%
Mostly Cloudy	51-99	9	67	76	15.70%
Cloudy	100	58	65	123	25.41%

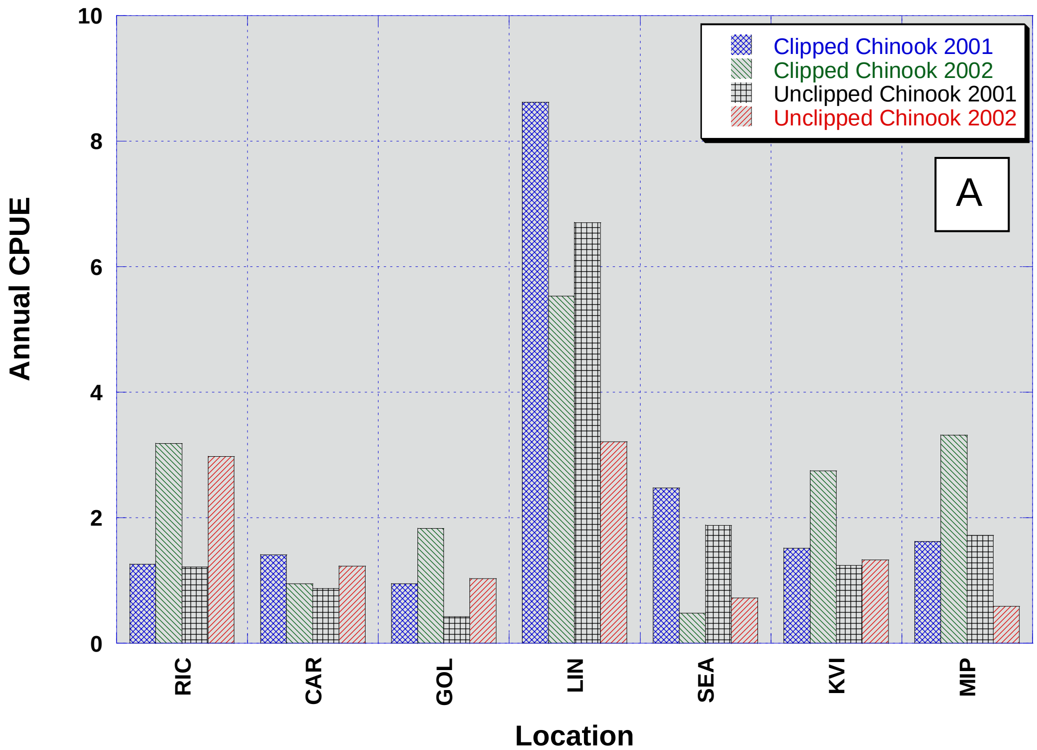
3.1.6.2. Environmental Relationships

Environmental variables were compared to the instantaneous CPUE of the different salmonids to see if fish abundance was related to environmental variables. Since each set had its own unique combination of environmental variables, each set was treated separately, versus comparing the mean CPUE for a given site on a given day. Thus, instantaneous CPUE always equals the total count of each species for that set. Furthermore, coho and Chinook were not broken into clipped and unclipped in order to create a larger sample size and increase the power of the statistical tests.

The instantaneous CPUE for Chinook, coho, chum, and cutthroat were not significantly different for the following environmental variables: tide height, tidal stage (ebb, slack, flood), and presence of drift vegetation (Wilcoxon; $p>0.1$).

The instantaneous CPUE of Chinook, chum and cutthroat were not significantly different for presence/absence of attached SAV. However, coho were caught at a significantly higher level at sites with attached SAV (Wilcoxon test; $p<0.05$). To further refine the analysis, SAV was broken into 3 categories: Zoestera, Ulva, and other. Instantaneous CPUE of coho was significantly higher for the Zoestera and the “other” categories versus the “no SAV” category (Wilcoxon test; $p<0.05$). There was no statistical difference between catch and the other three attached SAV categories.

Statistical analysis of instantaneous CPUE of Chinook and cutthroat were not significantly different for substrate based on the 4 substrate categories. The instantaneous CPUE of chum was significantly higher for the sand category than all other categories (Wilcoxon test; $p<0.05$). The instantaneous CPUE of coho was significantly higher for gravel substrates than all other categories (Wilcoxon test; $p<0.05$).



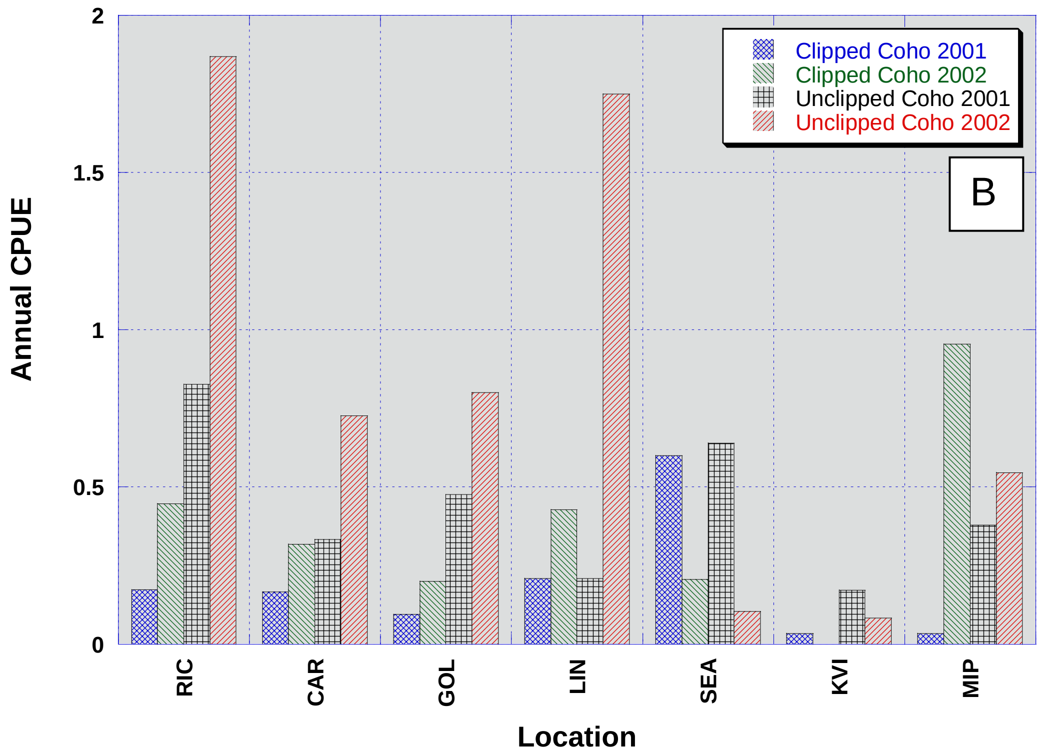
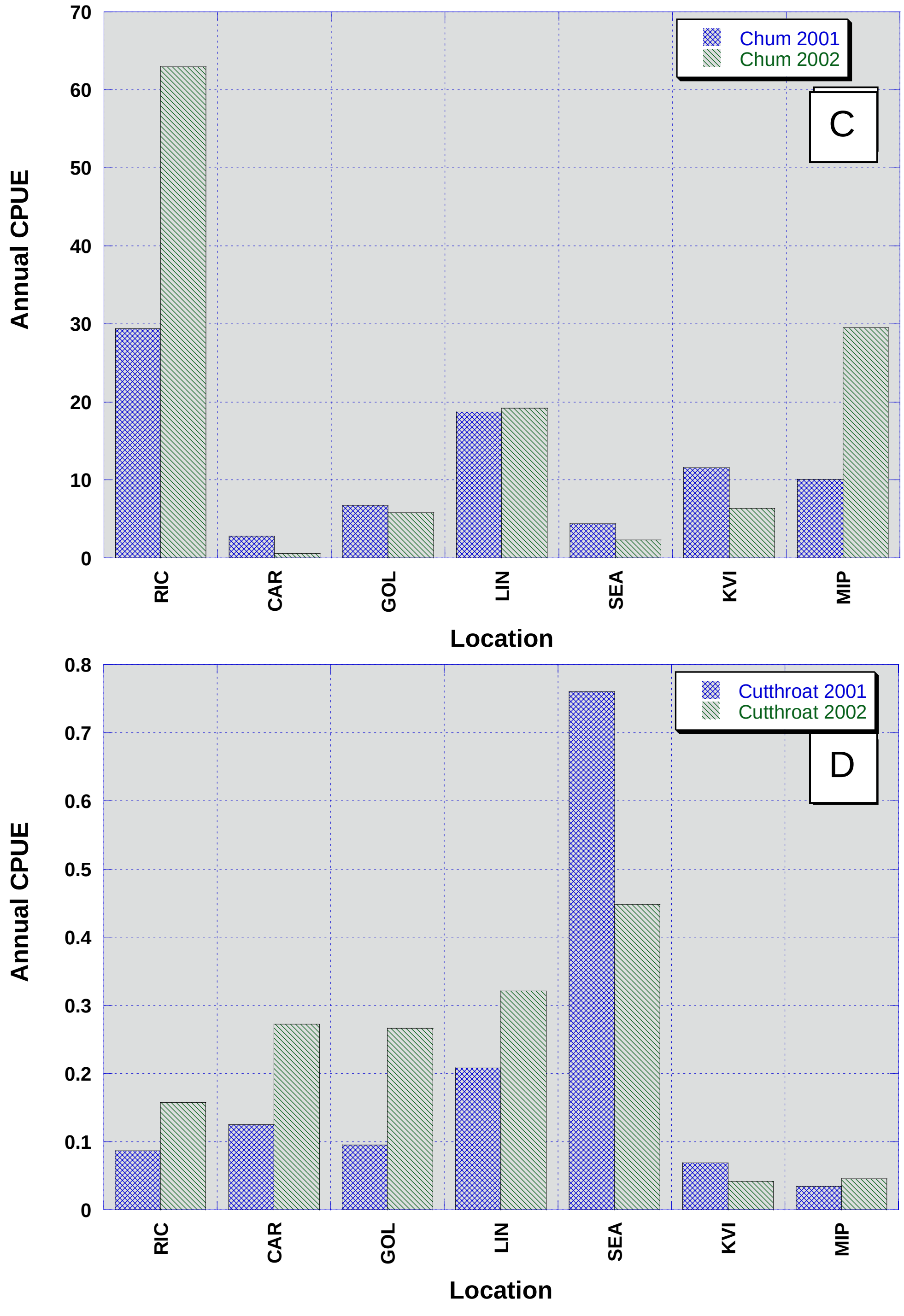


Figure 3.9. Annual CPUE for all index sites in 2001 and 2002, for a) Chinook, b) coho, c) chum, and d) cutthroat.
(Ric=Richmond Beach, Car=Carkeek Park, Gol=Golden Gardens, Lin=Lincoln Beach, Sea=Seahurst Park, KVI=KVI Beach, MIP=Maury Island Marine Park).

Figure 3.9 continued



2.1 Size

The mean length (FL) for all species encountered during these studies is reported in Table 3.13. Percent length frequencies were used to help differentiate size classes and seasonal occurrence of each size class. Size classes were evaluated mostly at 10 mm intervals, except for larger size classes (over 200 mm) and for cutthroat trout, which were grouped at 50 mm intervals. ANCOVA was used to test whether there was a difference in mean FL between years, hatchery or "wild" cohorts, or geographical region given the influence of sampling week, as a continuous variable (Table 3.14). In order to limit ANCOVA analysis to a specific year class of salmonid, only data from fish with lengths less than 200 mm were used. Natural-log transformed data were used in the statistical analyses to help mitigate the deviations from assumptions of normality and equality of variance. Statistical significance was measured at the 95% confidence level.

Size at capture for chum, pink and Chinook salmon indicated that most fish were in their first year of marine residence (0+ or subyearlings). The majority of the coho and sockeye caught were yearlings. The catch of cutthroat appeared to be made up of multiple year classes, based on the variability in sizes. In addition, larger cutthroat were caught throughout the study area (mean fork length of 261 mm). Like cutthroat, the few steelhead caught did not appear to be made up of one specific year class.

Table 3.13. Mean lengths and range of all measured salmonids caught in 2001-2002.

Speicies	N	Mean FL (mm)	Std Dev	Range (mm)
Chinook	2052	102.95	31.49	58-354
Coho	755	133.23	44.23	54-540
Chum	1650	63.99	21.22	32-190
Pink	171	40.20	7.87	28-65
Cutthroat	343	261.96	102.20	108-495
Sockeye	34	116.88	70.38	42-490
Steelhead	8	257.75	124.82	141-462

3.1.7.1. Chinook

A shift in the dominant size classes of Chinook salmon was observed between the two years (Figure 3.10). The dominant size classes in 2001 and 2002 measured 70 to 79.9 mm and 90 to 99.9 mm, respectively. These distributions represented 16% of measured Chinook in 2001 and 32% in 2002. The 2001 size classes were more broadly distributed, from 70 mm to 130 mm, than in 2002, where the majority of Chinook were more tightly distributed in size classes from 80 mm to 110 mm. In comparing the size classes of hatchery and "wild" Chinook for each year, similar size class proportions were found within years, except at the smallest size classes, which are dominated by hatchery Chinook (Figure 3.11 and 3.12). When analyzed by sample month for both years (Figure 3.13), length frequencies are similar between hatchery and "wild" Chinook within and between years. There is also a notable shift toward larger sizes in the catch after the month of July of both years. Mean length (FL) of Chinook was significantly greater in 2001 than in 2002 (Table 3.14). When analyzed by sample week, hatchery Chinook were statistically larger than "wild" Chinook in both years (Table 3.14). When compared by regions in 2001, the mean lengths of Chinook at the North Mainland and Vashon/Maury sites were equal, but both were significantly larger than Chinook at the South Mainland sites (Table 3.14). In 2002, the mean lengths of North Mainland Chinook were significantly larger than the other two regions (Table 3.14), which were not significantly different.

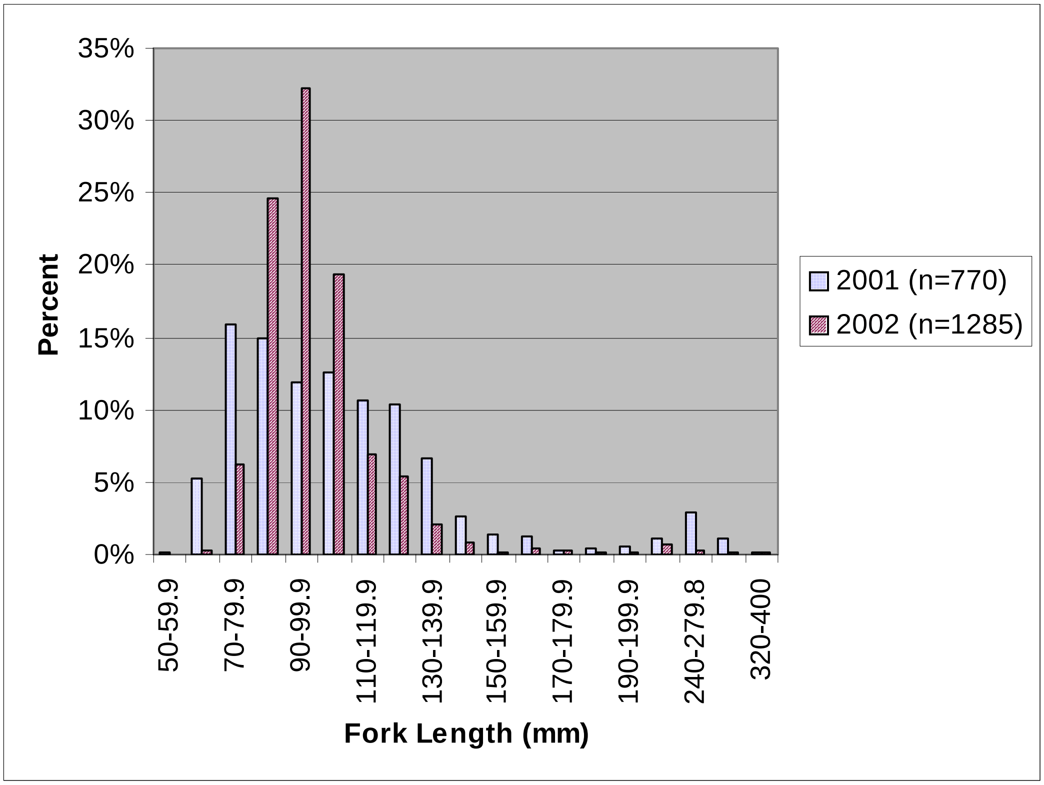


Figure 3.10. Percent of Chinook salmon by size class in 2001 and 2002.

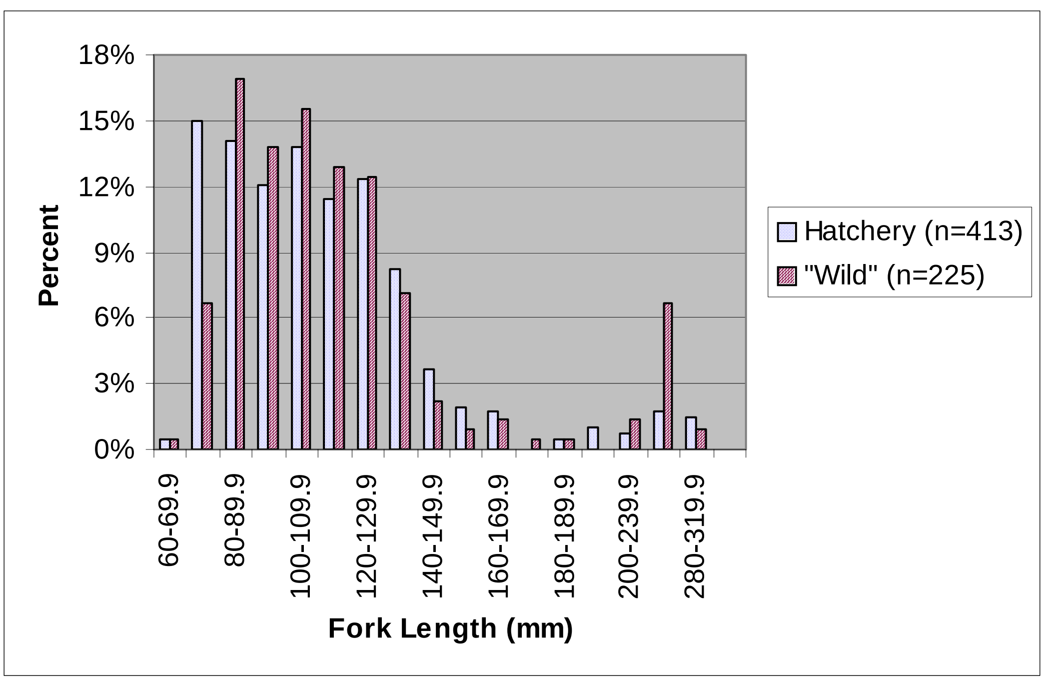


Figure 3.11. Percent of hatchery and “wild” Chinook salmon by size class in 2001.

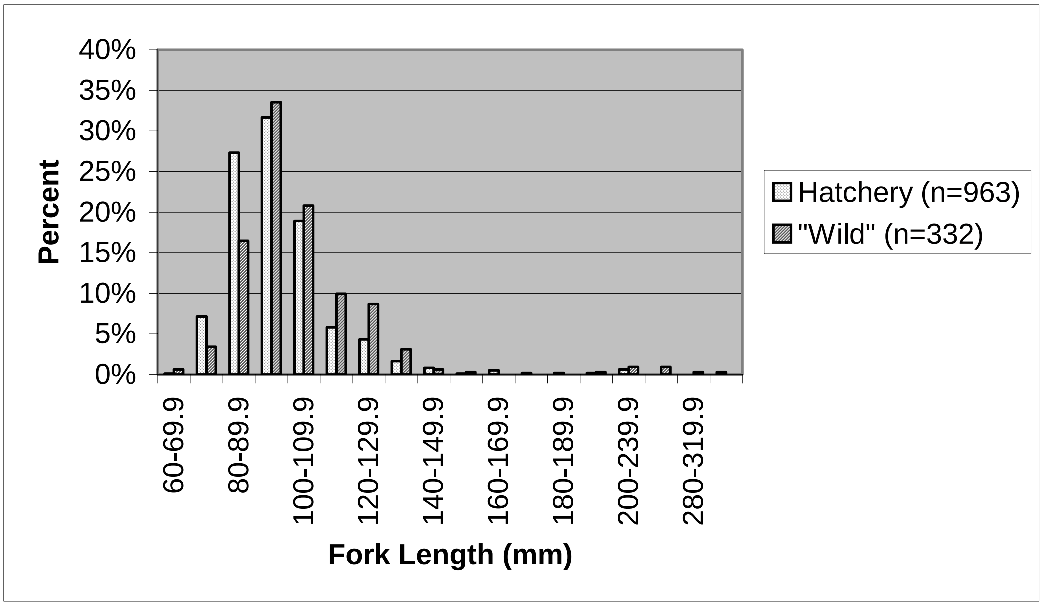


Figure 3.12. Percent of hatchery and “wild” Chinook salmon by size class in 2002.

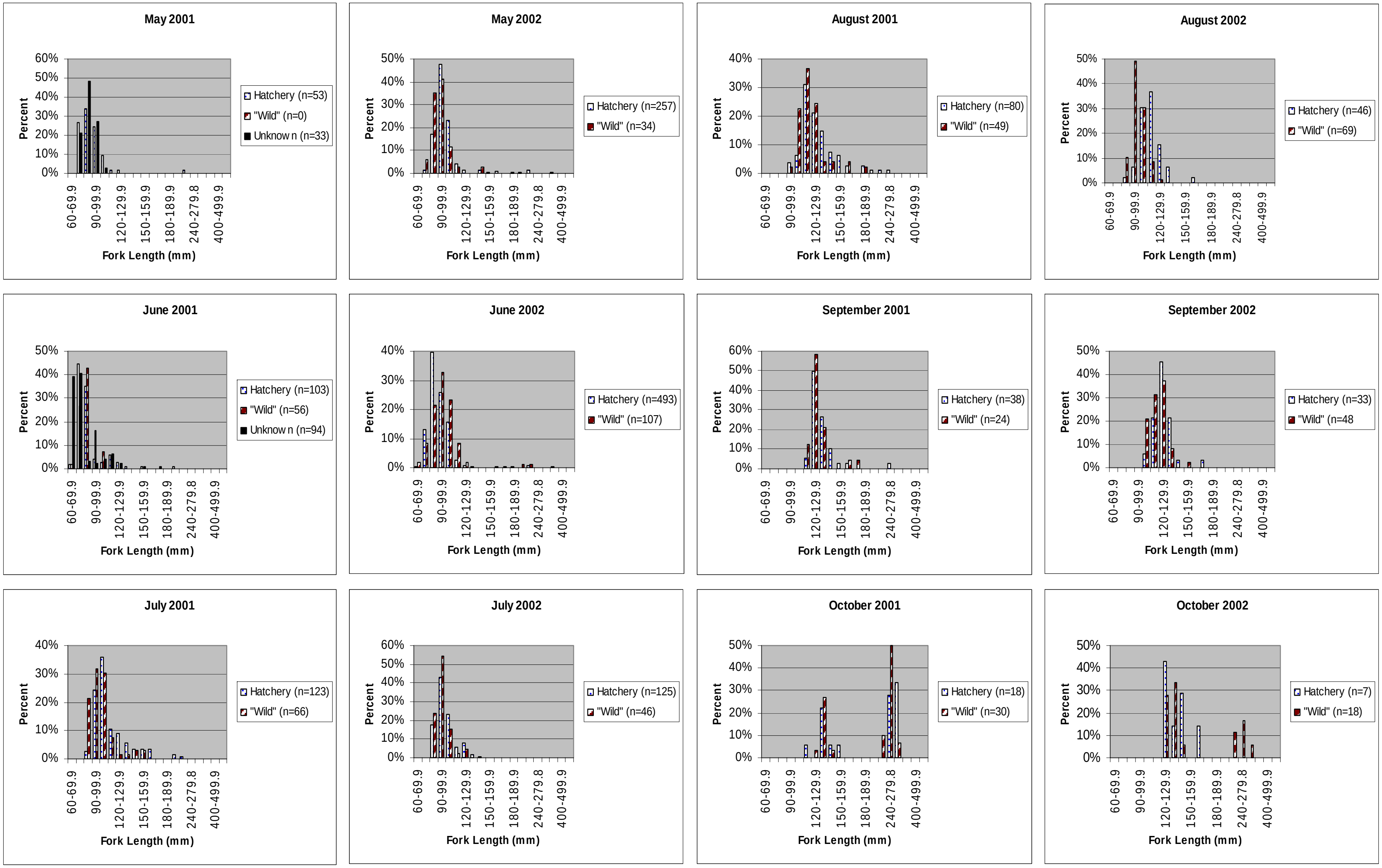


Figure 3.13. Percent of hatchery and "wild" Chinook salmon by size class and month in 2001 and 2002. May and June of 2001 had fish that were unclipped but not scanned for coded wire tags, therefore they are labeled as unknown origin.

3.1.7.2. Coho

There was a slight difference in the percent by size class between years, with a higher proportion of coho in the >150 mm size group in 2001, and in the 100 to 140 mm size range in 2002 (Figure 3.14). The proportion of hatchery and "wild" coho sizes were similar in 2001, which may be a result of not knowing the origin (hatchery or "wild") early in the sample period (Figure 3.15). However, in 2002, there was a distinct difference in the size classes of hatchery and "wild" coho, with hatchery coho being larger than "wild" coho (Figure 3.16). Specifically, the two largest size classes of "wild" coho combined (from 100 mm to 120 mm), represented 51% of the catch, whereas the two largest size classes of hatchery coho combined (from 130 mm to 150 mm), represented 58% of the catch. After May of 2002, the low numbers of coho, especially hatchery coho, do not allow for much comparison (Figure 3.17). The length frequencies by month for coho in 2001 do not show discernable patterns, though this is likely due to the low numbers of coho in 2001, and that hatchery coho were not distinguished from "wild" early in the season when they were more abundant. Mean length of coho was significantly greater in 2001 than in 2001 (Table 3.14). In 2002, the mean lengths of coho at the north mainland and Vashon/Maury sites were similar to each other and both were significantly larger than the south mainland sites (Table 3.14). When analyzed by sample week, hatchery coho were statistically larger than "wild" coho in both years (Table 3.14).

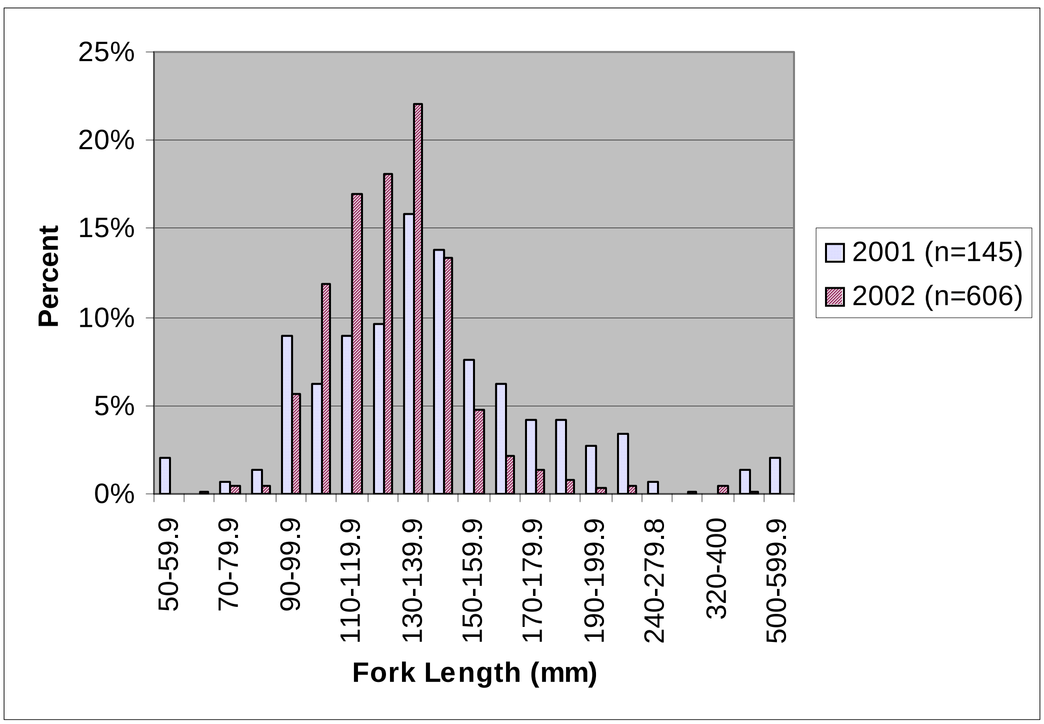


Figure 3.14. Percent of coho salmon by size class in 2001 and 2002.

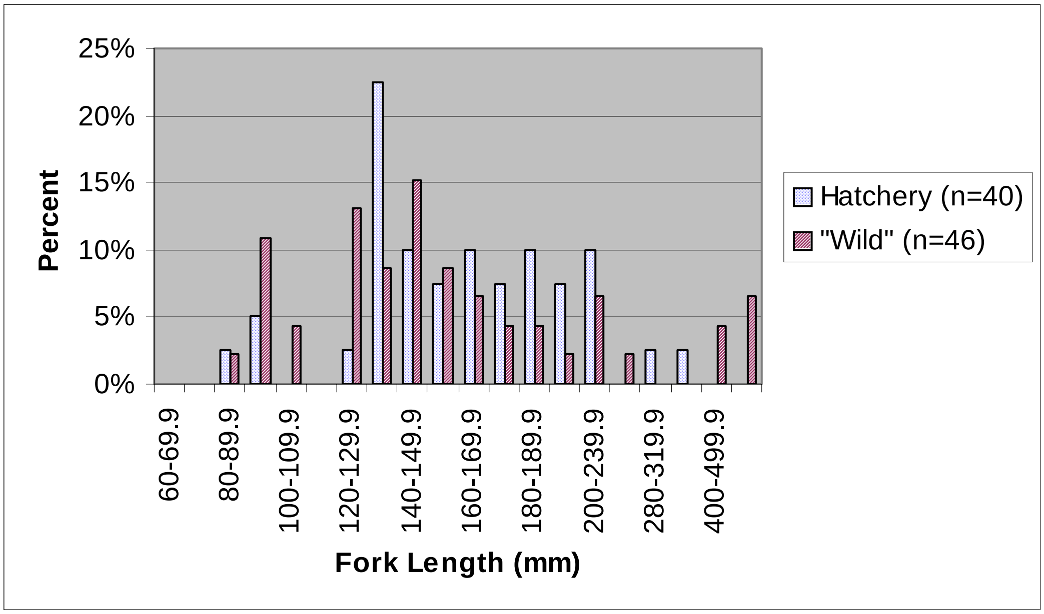


Figure 3.15. Percent of hatchery and "wild" coho salmon by size class in 2001.

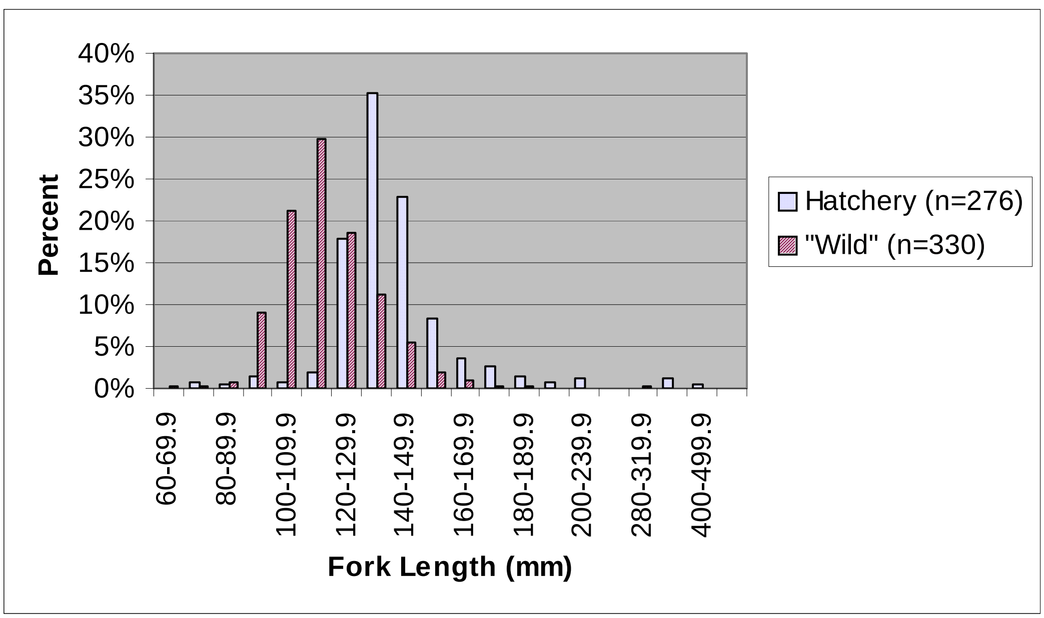


Figure 3.16. Percent of hatchery and "wild" coho salmon by size class in 2002.

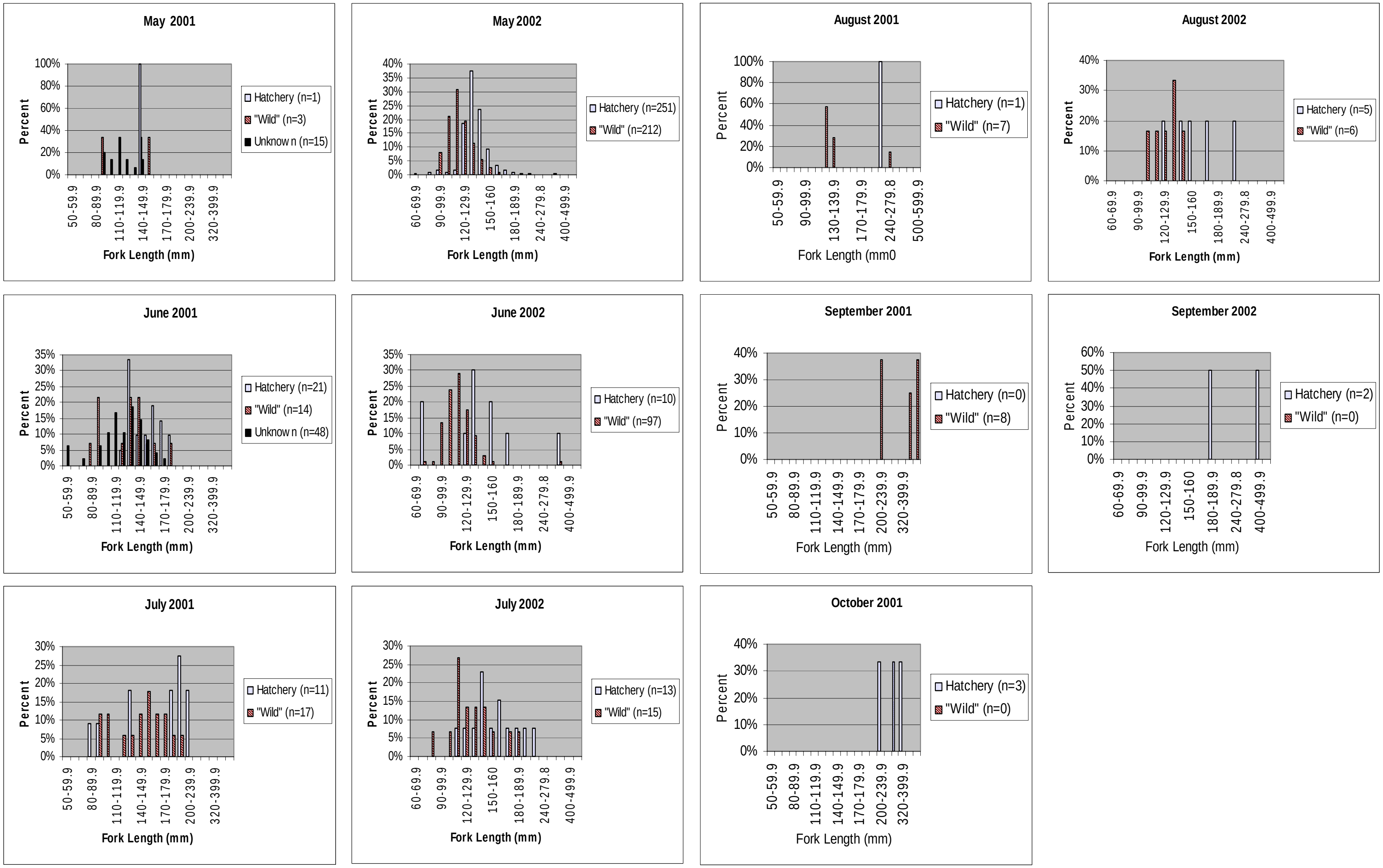


Figure 3.17. Percent of hatchery and "wild" coho salmon by size class and month in 2001 and 2002.

3.1.7.3. Chum

Chum in 2001 show a bimodal distribution with size class groupings at 60 mm to 80 mm and 150 mm to 160 mm (Figure 3.18). The size classes in 2002 were more uniform in their distribution around the 50 mm to 60 mm. Hatchery chum are not generally distinguishable from "wild" chum because they are not marked externally. When chum length frequencies were analyzed by month (Figure 3.19), the 2001 data show that the sizes increased as the year progressed, where during the last month of sampling only chum larger than 140 mm were caught. While there was an increase in size over time for chum in 2002, it was not as dramatic as in 2001, which may be partially explained by the fact that no chum were caught in September and October of 2002. Mean length of chum was significantly greater in 2001 than in 2002 (Table 3.14). Analyzing mean length by region in 2001 showed no significant difference (Table 3.14). In 2002, the mean length of north mainland chum was significantly larger than the other two regions, which were similar (Table 3.14).

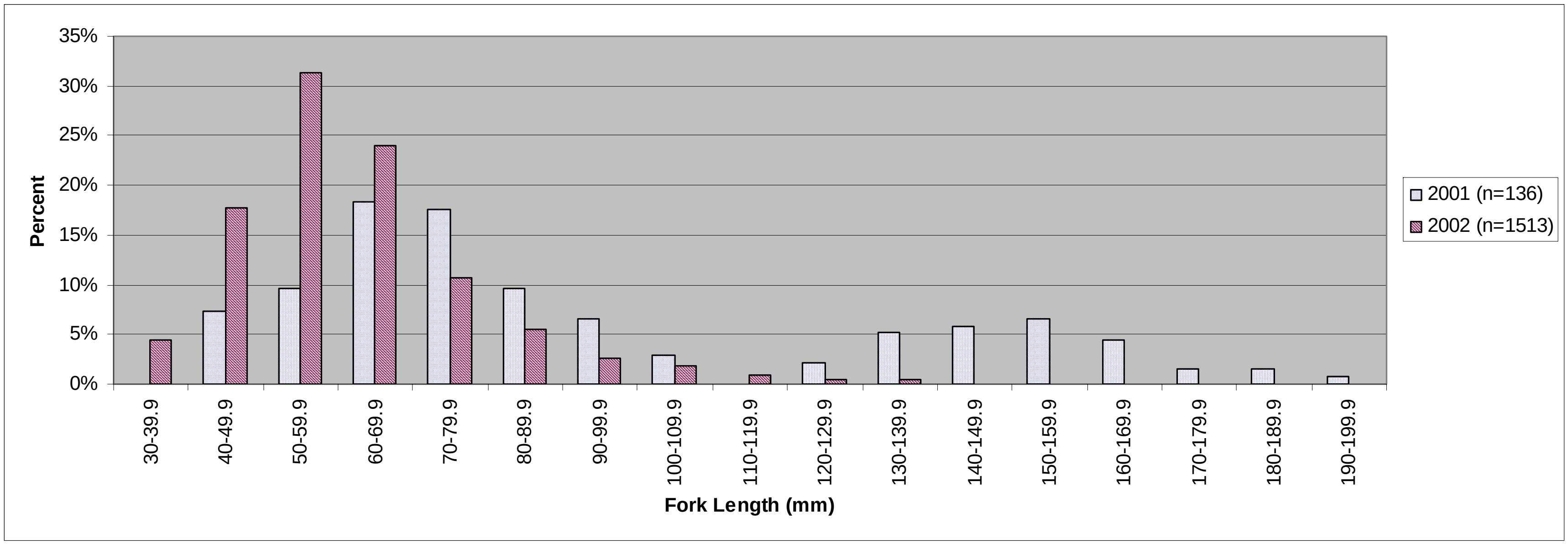


Figure 3.18. Percent of chum salmon by size class in 2001 and 2002.

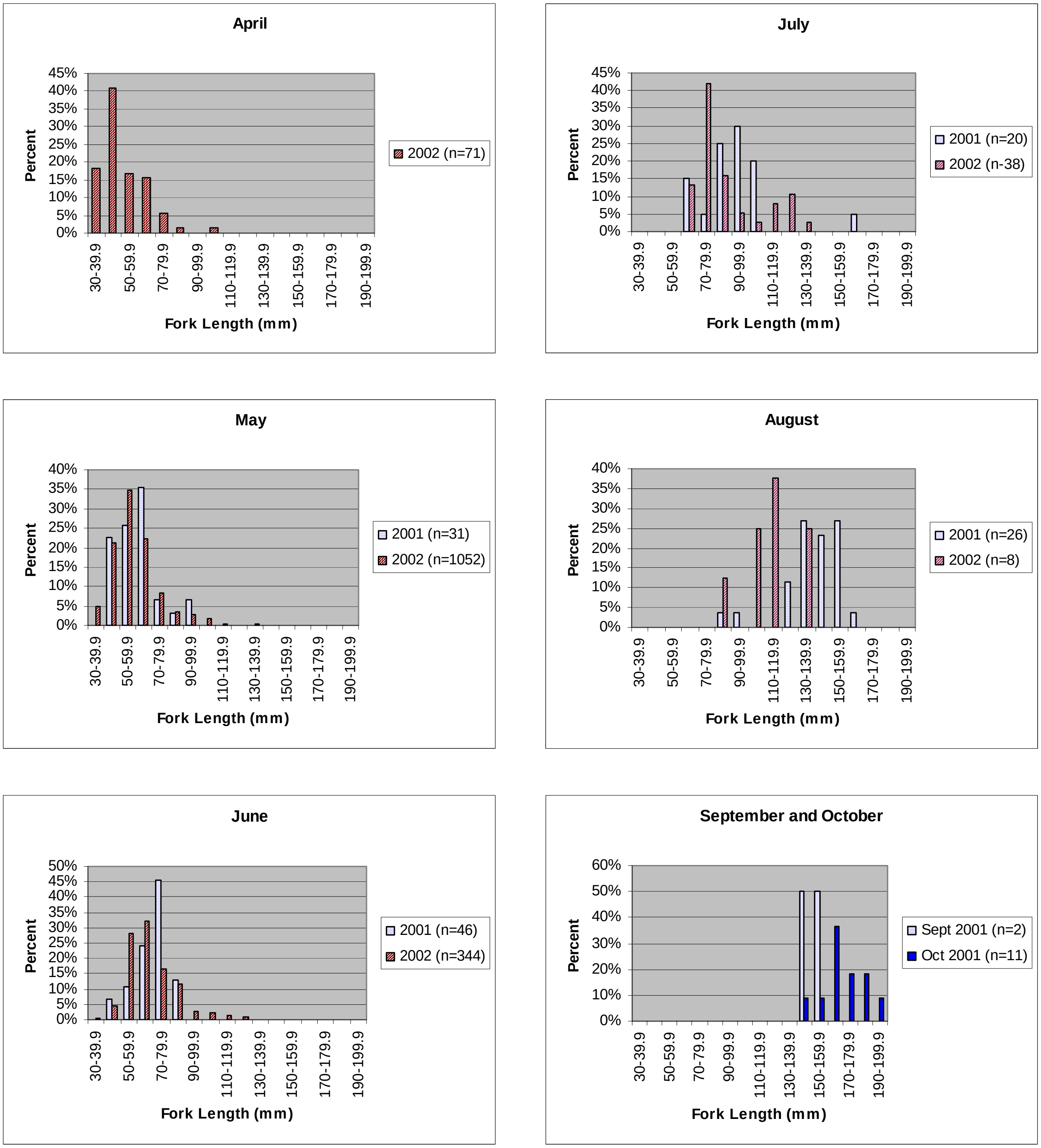


Figure 3.19. Percent of chum salmon by size class and month in 2001 and 2002.

3.1.7.4. Cutthroat

There appears to be a bimodal size distribution in both years, with one group under 200 mm and one group over 250 mm (Figure 3.20). Cutthroat trout length frequencies analyzed by month in 2001 and 2002 (Figure 3.21) show that small cutthroat (100 to 150 mm) appear in the catch in May through July. This size class is mostly absent in August, September, and October. The next smallest size class, 150 to 200 mm, is also mostly absent from the catch in September and October. The catch of larger size was more variable throughout the year. There was no significant difference in mean length of cutthroat between 2001 and 2002 (Table 3.14). However, by region, the mean length of cutthroat trout was significantly larger at north mainland sites than Vashon/Maury sites in both 2001 and 2002 (Table 3.14), which in turn were significantly greater than mean length at south mainland sites (Table 3.14).

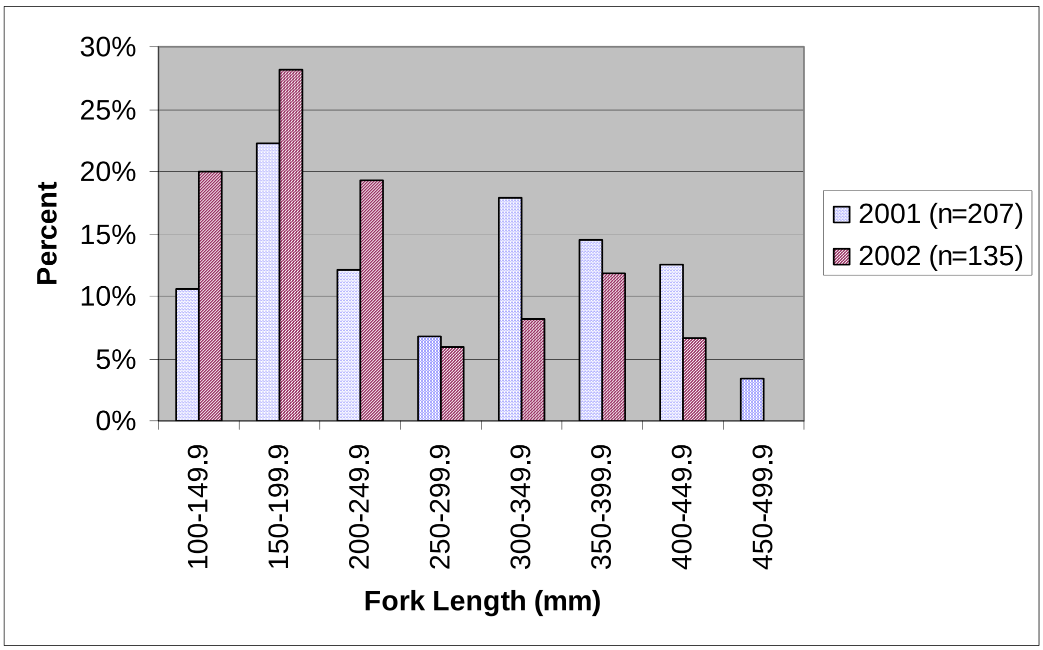


Figure 3.20. Percent of cutthroat trout by size class in 2001 and 2002.

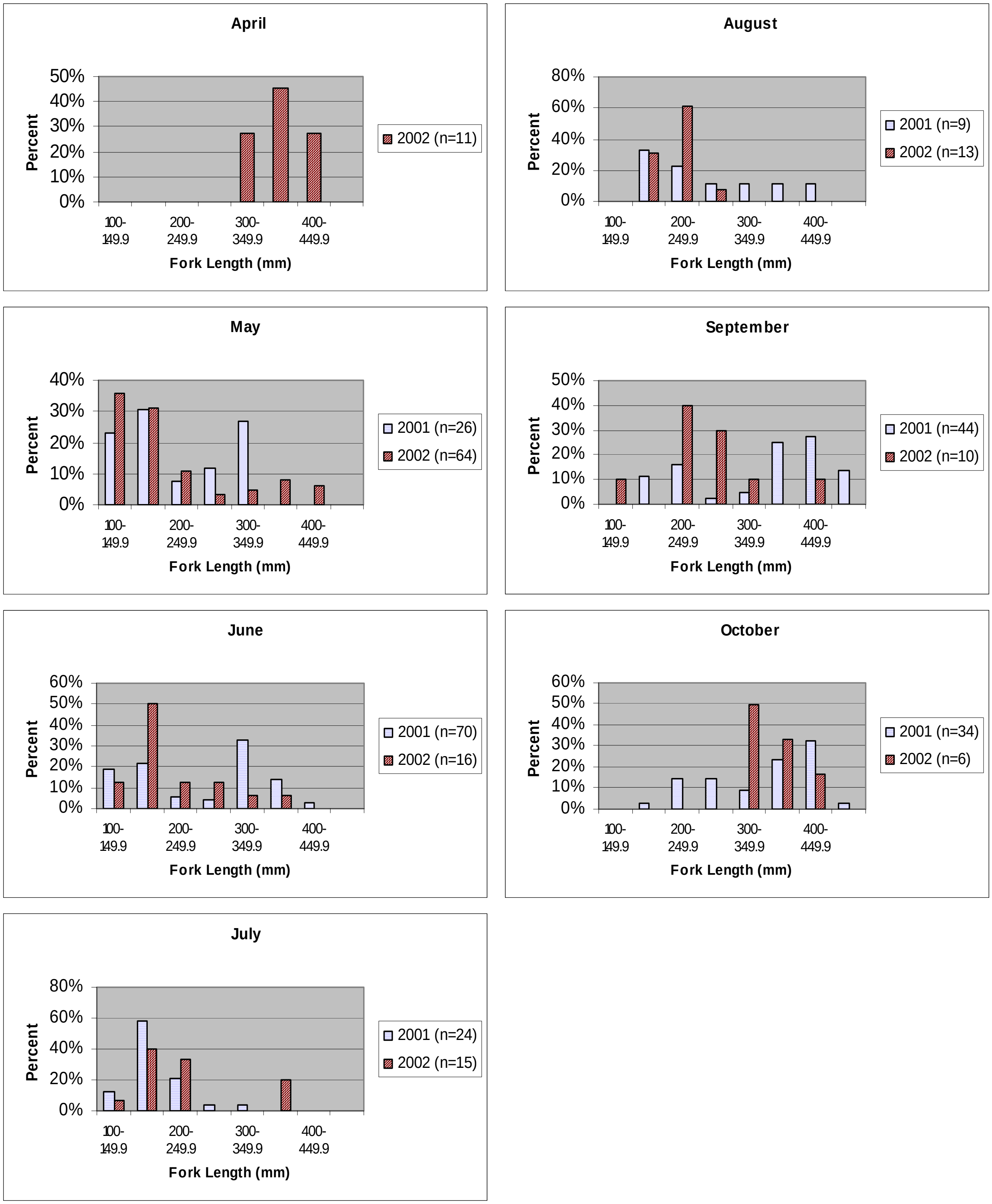


Figure 3.21. Percent of cutthroat trout by size class and month in 2001 and 2002.

Table 3.14. Summary of ANCOVA analyses for the length and weight of chinook, coho, chum, and cutthroat trout over time in 2001 and 2002.

(SD = Significantly Different α<0.05, NSD = Not Significantly Different α>0.05). Length comparisons were made on fish less than 200 mm.

	Chinook		Coho	
Treatment Groups	**Mean Size (mm) Accounting for Week**	**n**	**Mean Size (mm) Accounting for Week**	**n**
2001 v. 2002	SD: Mean of 2001 > 2002	2001 = 731 2002 = 1270	SD: Mean of 2001 > 2002	2001 = 135 2002 = 600
2001 v. 2002 Wild	SD: Mean of 2001 > 2002	2001 = 205 2002 = 315	SD: Mean of 2001 > 2002	2001 = 38 2002 = 329
2001 v. 2002 Hatchery	SD: Mean of 2001 > 2002	2001 = 397 2002 = 955	SD: Mean of 2001 > 2002	2001 = 34 2002 = 271
2001 Hatchery v. 2001 Wild (Unknown Excluded)	SD: Mean of Hatchery > Wild	Hatchery = 397 Wild = 205	SD: Mean of Hatchery > Wild	Hatchery = 34 Wild = 38
2002 Hatchery v. 2002 Wild (Unknown Excluded)	SD: Mean of Hatchery > Wild	Hatchery = 955 Wild = 315	SD: Mean of Hatchery > Wild	Hatchery = 271 Wild = 329
2001 by Region	SD: North Mainland=Vashon/Maury > South Mainland	North = 234 South = 351 Vashon = 146	NSD	North = 76 South = 46 Vashon = 13
2002 by Region	SD: North Mainland > Vashon/Maury = South Mainland	North = 392 South = 276 Vashon = 602	SD: North Mainland=Vashon/Maury > South Mainland	North = 329 South = 68 Vashon = 203

	Chum		Cutthroat	
Treatment Groups	**Mean Size (mm) Accounting for Week**	**n**	**Mean Size (mm) Accounting for Week**	**n**
2001 v. 2002	SD: Mean of 2001 > 2002	2001 = 104 2002 = 1514	NSD	2001 = 69 2002 = 65
2001 by Region	NSD	North = 20 South = 37 Vashon = 47	SD: North Mainland > Vashon/Maury = South Mainland	North = 40 South = 22 Vashon = 7
2002 by Region	SD: North Mainland > Vashon/Maury = South Mainland	North = 553 South = 138 Vashon = 823	SD: North Mainland > Vashon/Maury = South Mainland	North = 33 South = 15 Vashon = 17

3.2. CWT ANALYSIS

Juvenile Chinook and coho salmon captured during this study originated from hatcheries located throughout the Puget Sound. A total of 322 coded wire tagged fish were recovered from the 12 sites sampled in 2001 (n=122 Chinook; 7 coho) and the 16 sites sampled in 2002 (n=146 Chinook; 47 coho). Of the 322 CWT Chinook and coho recovered, 255 Chinook and 51 coho tags were decoded. Distribution, hatchery of origin, time-at-large and growth estimates were determined. Tagged fish originated from 14 hatcheries, located in 9 different watersheds in 2001, and 18 hatcheries, located in 11 different watersheds in 2002 (Figure 2.1). Combined, a total of 22 hatcheries, located in 13 different watersheds, were represented in the recaptures of tagged fish in this study (Tables 3.15 and 3.17).

3.2.1. Chinook

3.2.1.1. Origin and Capture location

In 2001, 77 CWT Chinook, representing 10 different hatchery stocks, were recovered at sampling locations within the boundaries of WRIA 9 (Table 3.15). Of the 77 Chinook, 26 (34%) originated from a hatchery within WRIA 9 (Soos Creek), while the Wallace River hatchery (WRIA 7) contributed 38 (51%) of the Chinook caught at WRIA 9 sampling locations. The remaining 13 Chinook (15%) recovered in WRIA 9 originated from eight other hatcheries, located north and south of the sampling area. Most tagged fish (n=55) were recaptured at three mainland sites; Lincoln Park (42%), Seahurst Park (18%), and Marine View (14%). However, the combined total of recaptures from three of the Vashon/Maury Island sites (Maury Island Park, KVI, Burton Park) equaled 26% of the total recoveries.

The 2001 recoveries of tagged Chinook in WRIA 8 yielded some similar, and surprisingly different, results (Table 3.15). Forty-three tagged Chinook, representing 7 different hatchery stocks, were recovered at sampling locations in WRIA 8. Of these Chinook, 18 (39%) originated from the Wallace River hatchery and 15 (37%) originated from the Grovers Creek hatchery (WRIA 15), located across Puget Sound to the west. Most of the tagged Chinook were recovered from the Meadowdale site (n=13), followed by the Carkeek (n=9) and Picnic Point (n=8) sampling sites, all located in the northern part of the study area.

With the exception of one site, sampling effort in 2001 ranged from 20-27 sets per site and total catch of CWT Chinook ranged from 3-31 per site (Table 3.16). Catch per unit of effort (CPUE) for CWT fish ranged from a low of 0.13 at the Ocean Avenue site to a high of 1.35 at the Lincoln Park site.

In 2002, 70 CWT Chinook, representing 8 different hatchery stocks were recovered at sampling locations within the boundaries of WRIA 9 (Table 3.17). Of the 70 Chinook, 27 (39%) originated from Soos Creek Hatchery (WRIA 9), while 28 (40%) of the Chinook came from the Wallace River Hatchery (WRIA 8). The remaining 15 Chinook recovered in WRIA 9 originated from six other hatcheries, all located in south Puget Sound with one exception, Grovers Creek hatchery, located northwest of WRIA 9 and across Puget Sound. Seventy percent of CWT Chinook (n=49) were recovered at three sites: Lincoln Park (40%) on the mainland; KVI (16%) on Vashon Island; and DNR Beach 83 (14%) on Maury Island. Of the remaining 21 CWT Chinook recaptures, 17 were recovered from four sites located on Vashon and Maury Islands. In sum, 46% of the tagged Chinook were recovered from mainland sites and 54% of tagged Chinook were recovered from island sites.

Table 3-15. Coded-Wire Tag recoveries by sample site and hatchery of origin in 2001.

	Hatchery of Origin and WRIA	Marble-mount Hatchery "WRIA 4"	White-Horse Pond "WRIA 5"	Bernie Gobin Hatchery "WRIA 7"	Wallace River Hatchery "WRIA 7"	Portage Bay Hatchery "WRIA 8"	Soos Creek Hatchery "WRIA 9"	Keta Creek Hatchery "WRIA 9"	Puyallup Tribal Hatchery "WRIA 10"	Voights Creek Hatchery "WRIA 10"	White River Hatchery "WRIA 10"	McAllister Hatchery "WRIA 11"	Tumwater Falls Hatchery "WRIA 13"	Grovers Creek Hatchery "WRIA 15"	Hupp Springs Rearing "WRIA 15"	Total CWT fish
capture location																
WRIA 8 (North)	Carkeek	2	1	0	6	0	0	0	0	0	0	0	0	0	0	9
	Meadowdale	0	0	0	* 5	0	0	0	0	0	0	0	0	8	0	13
	Ocean Ave	0	0	0	*1	1	0	0	0	0	0	0	0	2	0	4
	Picnic Point	1	0	0	3	0	0	0	0	0	0	0	0	4	0	8
	Richmond Beach	0	0	0	1	0	1	0	0	0	0	0	1	1	0	4
	Golden Gardens	0	0	0	2	0	3	0	0	0	0	0	0	0	0	5
	WRIA 8 totals	3	1	0	18	1	4	0	0	0	0	0	1	15	0	43
WRIA 9 (South & Vashon/ Maury Islands)	Burton Park	0	1	1	1	2	0	0	0	0	0	1	0	0	0	6
	KVI	0	0	0	0	0	2	0	1	0	1	0	2	0	0	6
	Maury Island	0	0	0	*6	0	*2	0	0	*1	0	0	0	0	1	10
	Lincoln Park	0	0	0	11	0	19	0	0	0	1	0	0	0	0	31
	Seahurst	0	0	0	13	0	0	0	0	0	0	0	0	0	0	13
	Marine View	0	0	0	7	0	3	*1	0	0	0	0	0	0	0	11
	Tramp Harbor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	WRIA 9 totals	0	1	1	38	2	26	1	1	1	2	1	2	0	1	77
	Total per hatchery	3	2	1	56	3	30	1	1	1	2	1	3	15	1	120

The 2002 recoveries of tagged Chinook in WRIA 8 represented 10 hatcheries, located in 8 different watersheds. Of the 71 tagged Chinook recovered in WRIA 8 during this sampling period, 51 (72%) originated from three hatcheries; Wallace River (34%), Grovers Creek (24%), and Samish (14%). Most of the tagged Chinook were recovered at the Richmond Beach site (54%), followed by Carkeek Park (18%) and Golden Gardens (18%).

In 2002, the sampling effort for the index sites ranged from 22-41 sets per site and the catch of Chinook per site ranged from 2-38 CWT Chinook (Table 3.18). Catch per unit of effort for the index sites ranged from a low of 0.09 CWT Chinook at Maury Island Park to a high of 1.00 at Lincoln Park (Table 3.18). The Richmond Beach site also had a high CPUE of 0.93 and several of the non-index sites had a high CPUE (DNR 83 = 3.33; Talequah = 1.17; Point Robinson = 0.70).

Table 3-16. Number and percentage of Coded-Wire Tagged Chinook and coho caught in 2001 by site.

2001					
Site	# caught	%	# stocks	Effort	CPUE
Richmond Beach	4	3.51%	4	22	0.18
Lincoln Park	31	27.19%	3	23	1.35
Carkeek Park	9	7.89%	3	22	0.41
Golden Gardens	5	4.39%	2	21	0.24
KVI	6	5.26%	4	27	0.22
Maury Island Park	7	6.14%	3	25	0.28
Meadowdale	12	10.53%	2	24	0.50
Picnic Point	8	7.02%	3	25	0.32
Seahurst	13	11.40%	2	25	0.52
Burton	6	5.26%	5	20	0.30
Marine View	10	8.77%	2	21	0.48
Ocean Ave	3	2.63%	2	23	0.13
Tramp Harbor	0	0.00%	0	1	0.00
Totals	114	100.00%			

Table 3-17. Coded-Wire Tag recoveries by sample site and hatchery of origin in 2002

	Hatchery of Origin and WRIA	Lummi Sea Ponds "WRIA 1"		Samish Hatchery WRIA 3		Marblemount Hatchery "WRIA 4"		Bernie Gobin Hatchery "WRIA 7"		Wallace River Hatchery "WRIA 7"		Issaquah Creek Hatchery "WRIA 8"		Soos Creek Hatchery "WRIA 9"		Keta Creek Hatchery "WRIA 9"		Elliot Bay Net Pens "WRIA 9"	
		coho	Chinook	coho	Chinook	coho	Chinook	coho	Chinook	coho	Chinook	coho	Chinook	coho	Chinook	coho	Chinook	coho	Chinook
capture location																			
WRIA 8 (North)	Picnic Point	0	0	0	0	0	1	0	3	4	0	1	0	1	0	0	0	0	0
	Meadowdale	0	0	0	0	0	1	0	2	4	0	9	0	0	0	0	0	0	0
	Edmonds	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Deer Creek	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0
	Richmond Beach	0	2	0	10	1	1	0	1	0	8	3	0	0	1	0	0	0	0
	Carkeek	0	0	0	0	0	0	0	0	0	9	0	0	1	1	0	0	0	0
	Golden Gardens	0	0	0	0	0	0	0	1	0	7	1	0	0	3	0	0	0	0
	WRIA 8 totals	0	2	0	10	1	3	0	7	8	24	18	0	2	5	0	0	0	0
WRIA 9 (South & Vashon/ Maury Islands)	Lincoln Park	0	0	0	0	0	0	0	0	0	16	0	0	0	9	1	0	1	0
	Seahurst	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
	KVI	0	0	0	0	0	0	0	0	0	3	0	0	0	5	0	0	0	0
	DNR Beach 83	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0
	Point Robinson	0	0	0	0	0	0	0	0	0	5	0	0	0	2	0	0	0	0
	Maury Island	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	Burton Park	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Talequah/KLP1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Camp Sealth	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
	EEG1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	KLP2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	SGF2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	SGF1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	SGB2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	SGB1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Mud 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Mud 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	EEG2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	WRIA 9 totals	0	0	0	0	0	0	0	0	0	28	0	0	0	27	1	0	1	0
	Total per hatchery	0	2	0	10	1	3	0	7	8	52	18	0	2	32	1	0	1	0

Table 3-17 continued

	Hatchery of Origin and WRIA	Puyallup Tribal Hatchery "WRIA 10		Voights Creek Hatchery "WRIA 10"		White River Hatchery "WRIA 10"		Nisqually Hatchery "WIRA 11"		South Sound Net Pens "WRIA 14"		Port Gamble Net Pens "WRIA 15"		Grovers Creek Hatchery "WRIA 15"		Hupp Springs Rearing "WRIA 15"		Dungeness Hatchery "WRIA 18"		Total CWT fish	
		coho	Chinook	coho	Chinook	coho	Chinook	coho	Chinook	coho	Chinook	coho	Chinook	coho	Chinook	coho	Chinook	coho	Chinook	coho	Chinook
capture location																					
WRIA 8 (North)	Picnic Point	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	8	4
	Meadowdale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	3
	Edmonds	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Deer Creek	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
	Richmond Beach	0	1	0	0	0	1	0	0	0	0	0	0	0	13	0	0	0	0	4	38
	Carkeek	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	1	13
	Golden Gardens	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	13
	WRIA 8 totals	1	1	0	0	0	1	0	0	0	0	2	0	0	17	0	0	0	1	32	71
WRIA 9 (South & Vashon/ Maury Islands)	Lincoln Park	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	1	0	0	3	28
	Seahurst	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	4
	KVI	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	11
	DNR Beach 83	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
	Point Robinson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
	Maury Island	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	2
	Burton Park	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Talequah/ KLP1	0	1	5	0	0	1	0	5	0	0	0	0	0	0	0	0	0	0	5	7
	Camp Sealth	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	EEG1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	KLP2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	SGF2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	SGF1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	SGB2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	SGB1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Mud 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Mud 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	EEG2	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
	WRIA 9 totals	0	2	10	0	0	4	0	7	1	0	0	0	0	1	0	1	0	0	13	70
	Totals per hatchery	1	3	10	0	0	5	0	7	1	0	2	0	0	18	0	1	0	1		

Table 3-18. Number and percentage of Coded Wire Tagged Chinook caught in 2002 by site (*=Index Sites).

Site	# caught	%	# of stocks	Effort	CPUE
*Richmond Beach	38	26.39%	9	41	0.93
*Lincoln Park	28	19.44%	4	28	1.00
*Carkeek Park	13	9.03%	4	22	0.59
DNR Beach 83	10	6.94%	1	3	3.33
*Golden Gardens	13	9.03%	4	30	0.43
*KVI	11	7.64%	4	24	0.46
*Maury Island Park	2	1.39%	2	22	0.09
Meadowdale	3	2.08%	2	12	0.25
Picnic Point	7	4.86%	2	13	0.54
Point Robinson	7	4.86%	2	13	0.54
*Seahurst	4	2.78%	2	29	0.14
KLP 1	7	4.86%	3	6	1.17
Deer Creek	0	0.00%	0	2	0.00
Edmonds	0	0.00%	0	4	0.00
Burton	0	0.00%	0	5	0.00
Camp Sealth	1	0.69%	1	8	0.13
KLP2	0	0.00%	0	5	0.00
EEG1	0	0.00%	0	5	0.00
EEG2	0	0.00%	0	6	0.00
MD1	0	0.00%	0	4	0.00
MD2	0	0.00%	0	4	0.00
SGB1	0	0.00%	0	5	0.00
SGB2	0	0.00%	0	5	0.00
SGF1	0	0.00%	0	5	0.00
SGF2	0	0.00%	0	5	0.00
Totals	144	100.00%			

3.2.1.2. Net Direction of Travel

The distribution of CWT Chinook was variable within and between sampling sites and sampling years. However, some patterns of distribution did emerge based upon analysis of CWT Chinook recaptures. In general, CWT Chinook displayed a variety of movement patterns, which did not simply follow the shoreline in a unidirectional manner. Recaptured CWT fish moved from south to north, north to south, east to west and west to east, sometimes moving great distances in short periods of time, or crossing the open (deeper) waters of Puget Sound to get to Vashon and Maury Islands. See, for example, the spatially displayed movement patterns of CWT Chinook from the Wallace River hatchery (Figure 3.22), Green River hatchery (Figure 3.23), and Grovers Creek hatchery (Figure 3.24). Please note that the lines drawn connecting hatchery and recapture locations are simply meant to suggest a net direction of movement, not a path.

CWT Chinook from hatcheries north of WRIA 7 (e.g., Marblemount, Lummi hatcheries) were caught only at WRIA 8 sample sites in both 2001 and 2002 (Tables 3.15 and 3.17), indicating a net southerly direction of travel. Recaptures of CWT Chinook from hatcheries on the west side of Puget Sound (e.g., Port Gamble and Grovers Creek hatcheries) exhibited a net easterly pattern of movement, with all but one fish recapture occurring at WRIA 8 sampling locations. In addition, one CWT Chinook that originated from the Dungeness hatchery was recaptured in WRIA 8 exhibiting a net southeasterly pattern of movement (Figure 3.25). The majority (92%) of the CWT Chinook recaptures from hatcheries south of WRIA 10 (e.g., Nisqually hatchery, South Sound Net Pens) were caught within WRIA 9 for 2001 and 2002 combined, which indicates a net northerly movement pattern.

For 2001 and 2002 combined, approximately 86% of the 59 CWT Chinook salmon originating from the Soos Creek Hatchery were caught south of their entry point into Puget Sound, and few individuals were recaptured at sampling sites located in WRIA 8. Most of the CWT Chinook recaptures from hatcheries located in WRIA 10 were caught in WRIA 9 in both 2001 (100%) and 2002 (80%). In 2001, only 3 CWT Chinook originated from WRIA 8 hatcheries. Two were recaptured in WRIA 9 and the other was recaptured in WRIA 8. In 2002, a lower percentage of CWT Chinook were released from WRIA 8 hatcheries. Wallace River Hatchery (WRIA 7) CWT Chinook were recaptured in both WRIAs 8 and 9 in 2001, with 30% in WRIA 8 and 70% in WRIA 9. In 2002, 52 CWT Chinook from the Wallace River Hatchery were recaptured, with 46 % caught in WRIA 8 and 54% caught in WRIA 9.

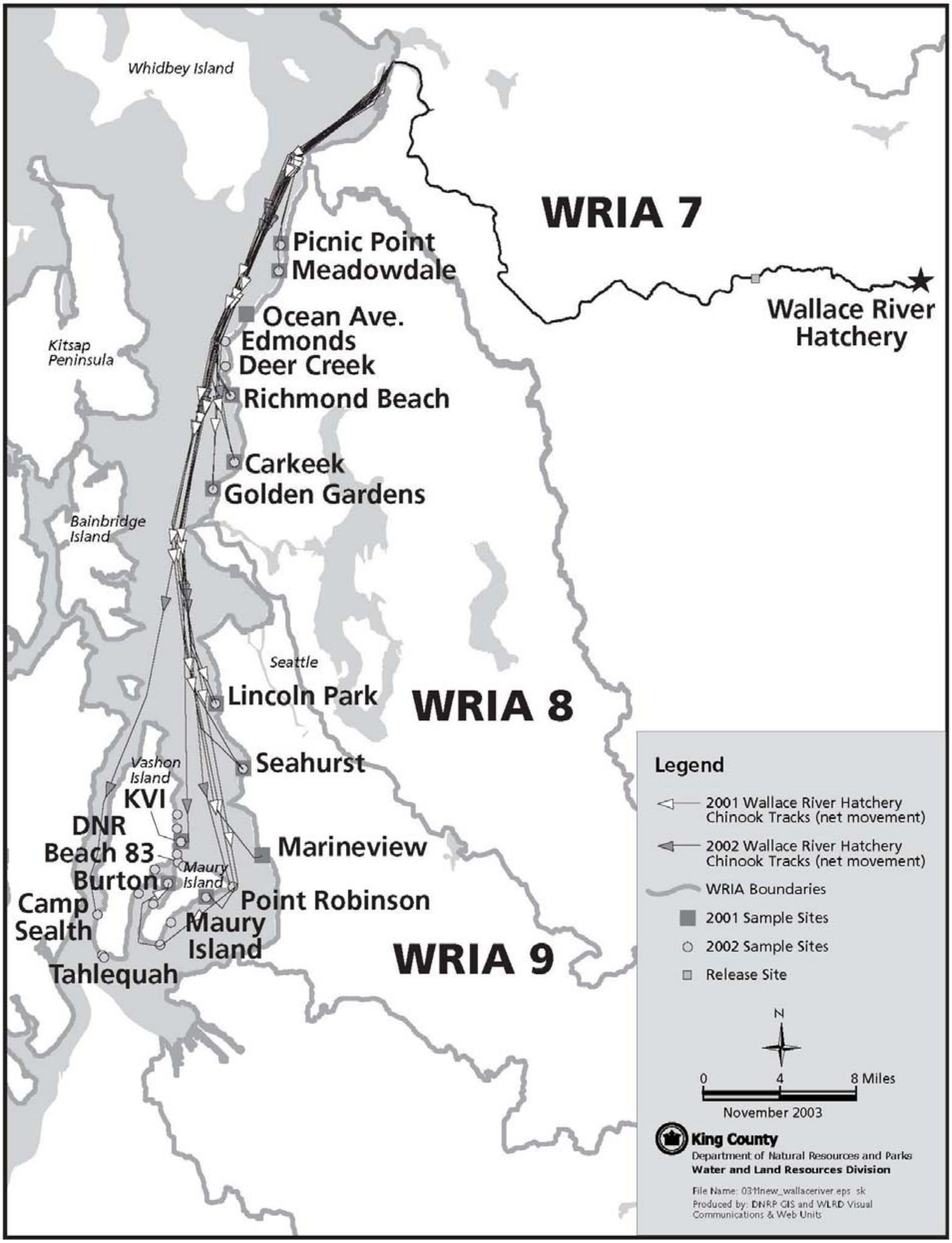


Figure 3.22. Wallace River hatchery Chinook recapture locations 2001 and 2002.

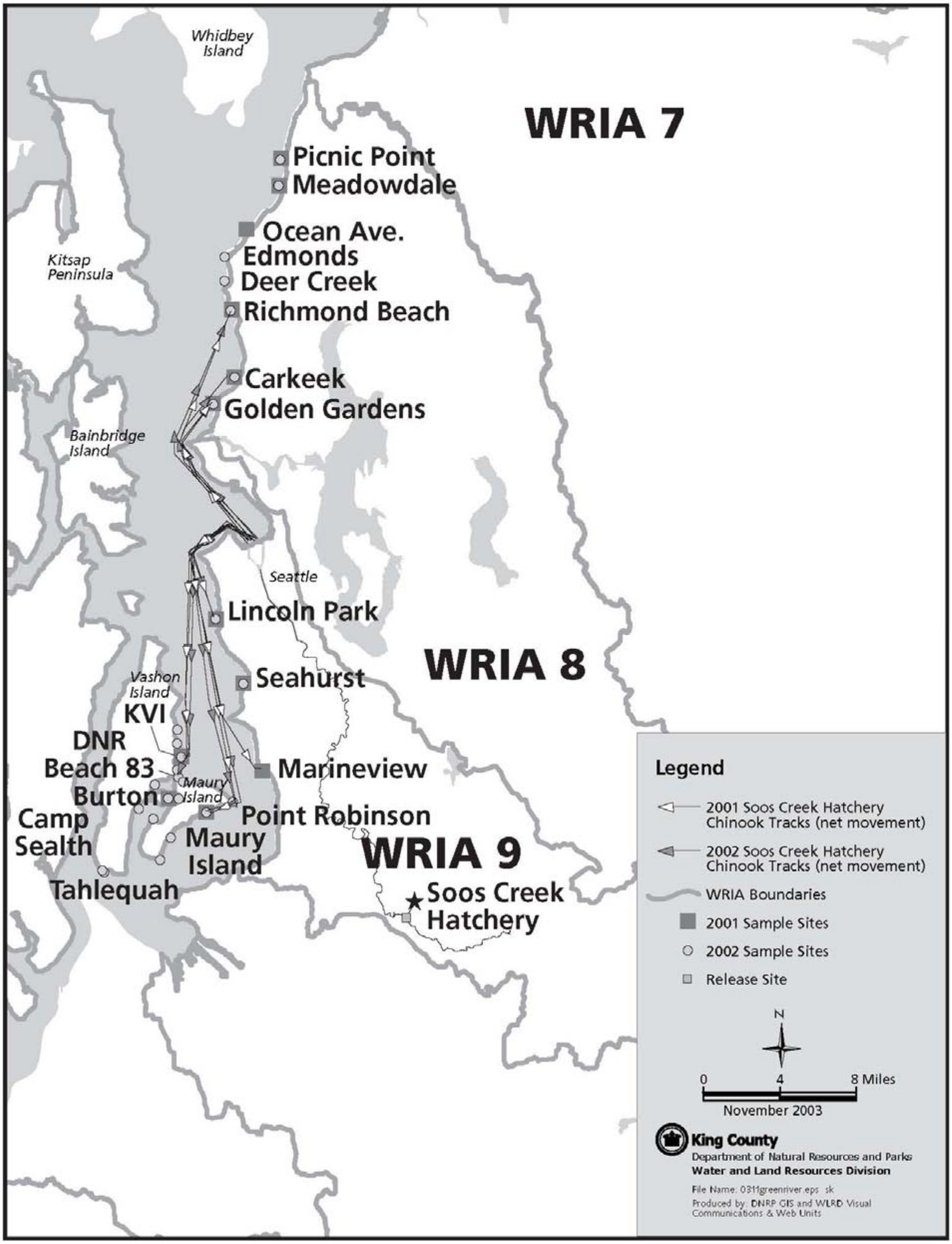


Figure 3.23. Green River hatchery Chinook recapture locations 2001 and 2002.

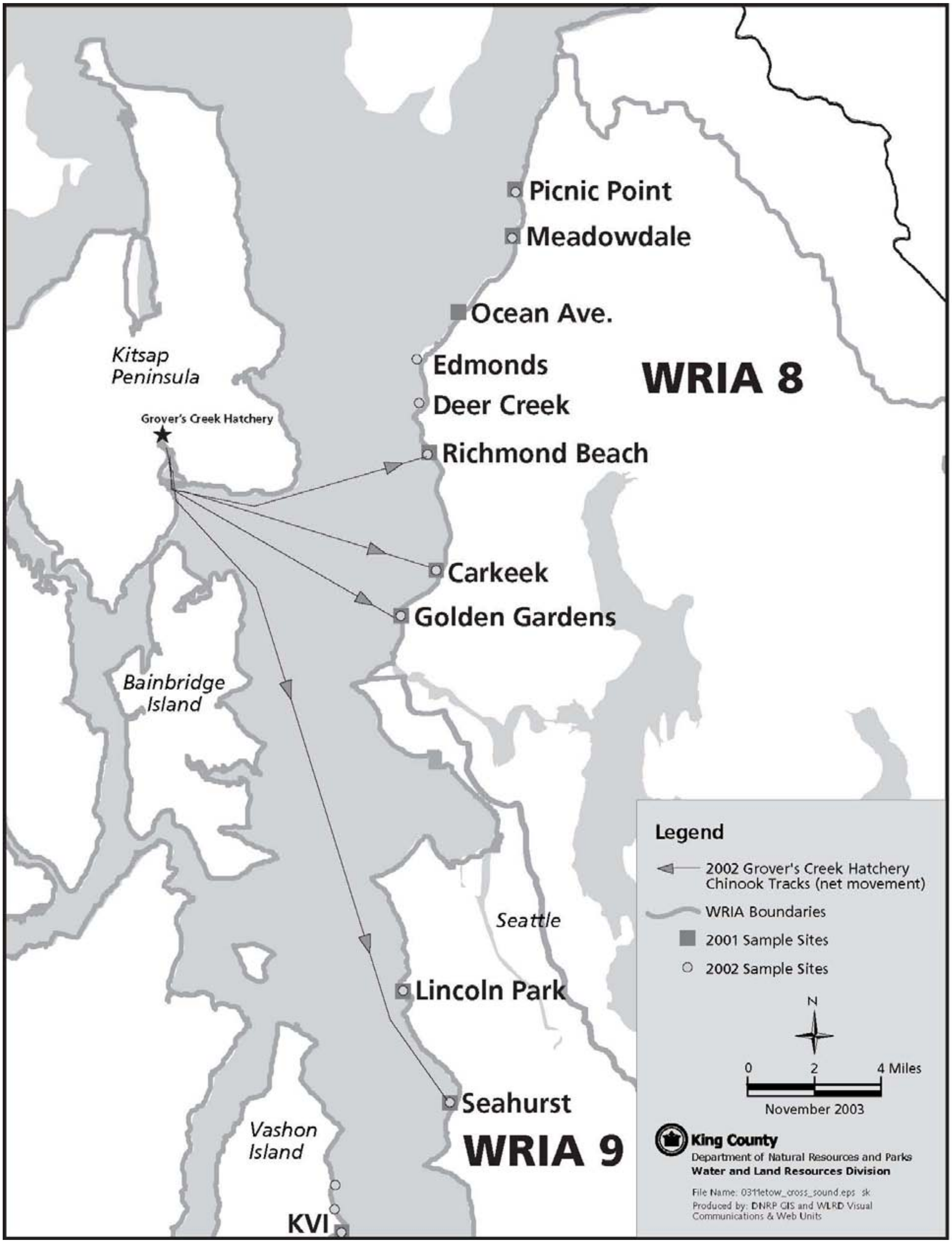


Figure 3.24. Cross sound movement of Grover's Creek hatchery Chinook in 2002.

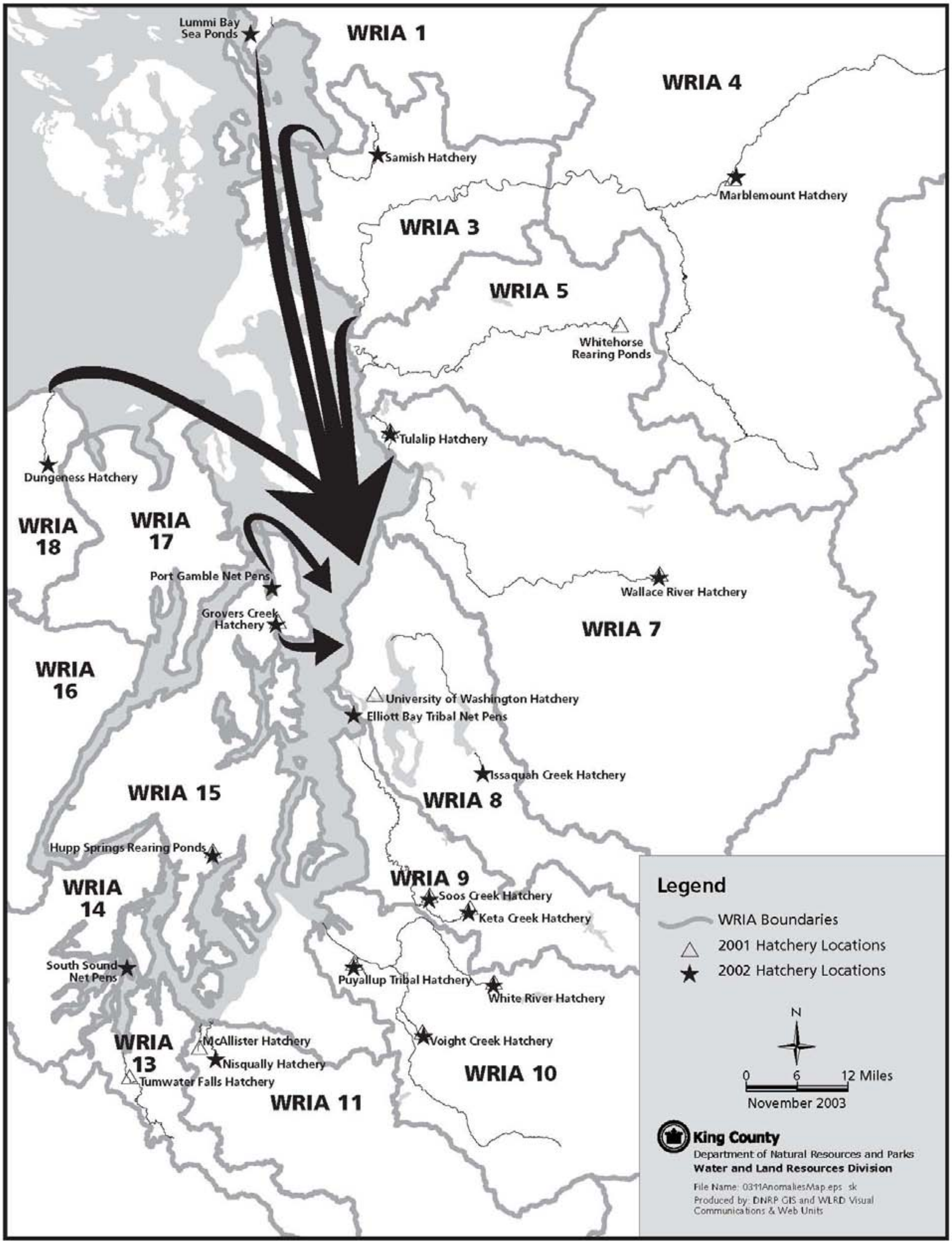


Figure 3.25. Unexpected movement patterns of North and western hatchery Chinook.

3.2.1.3. Time-at-Large

Time-at-large for CWT Chinook ranged from 0 to 112 days in 2001 and from 0 to 128 days in 2002. In 2001, CWT recaptured Chinook were released from April 1 through June 29. In 2002, CWT Chinook were released from April 12 through October 2. The majority of CWT Chinook were caught within 40 days of the time of release in both 2001 (63%) and 2002 (79%). It is important to note that some Chinook are volitionally released over a one- to four-week period, making it difficult to identify the exact time-at-large. Furthermore, time spent in freshwater versus marine water after release in unknown.

Coded wire tagged fish from 3 hatcheries were recaptured in great enough quantities to indicate patterns in time-at-large. In 2001, 30% of the Wallace River Chinook were caught in WRIA 8, and 70% in WRIA 9. All 3 of the Wallace River CWT Chinook caught earlier than 14 days-at-large were caught in WRIA 8. Thirty-eight percent of the CWT Wallace River Chinook were caught after being at-large for more than 59 days in 2001. In 2002, 46% and 54% of CWT Wallace River Chinook were caught in WRIAs 8 and 9, respectively. Eighty-nine percent of Wallace River Chinook at-large less than 17 days were recaptured in WRIA 8. The majority (83%) of Wallace River Hatchery Chinook were caught at least 30 days after release, with 29% of all Wallace River CWT Chinook being caught later than 59 days after release. For all CWT Chinook caught in 2002, Wallace River Hatchery Chinook represent 75% of the Chinook caught after 59 days-at-large.

Coded wire tagged Chinook released from Grover’s Creek hatchery were caught within 4 days of release in 2001, and within 6 to 17 days in 2002. In 2001, all Grover’s Creek CWT Chinook were caught within 19 days-at-large. In 2002, all Grover’s Creek CWT Chinook were caught within 21 to 30 days (volitional release period).

Coded wire tagged Chinook from the Soos Creek hatchery were caught between 0 and 104 days-at-large in 2001. In 2002, Soos Creek CWT Chinook were caught between 0 to 93 days-at-large. In 2001, the majority (85%) of CWT Soos Creek Chinook were caught within 4 weeks of release. In 2002, the majority (81%) of CWT Soos Creek Chinook were caught within 2 weeks of release. Only a few fish were caught after being at-large for more than 90 days in both 2001 and 2002.

3.2.1.4. Minimum Distance Traveled

In order to estimate distance traveled, a straight-line estimate (through waterways) from the point of release to the point of recapture (i.e., the only two data points available) was made. This distance includes the freshwater distance traveled from release point. Therefore, the estimated distances represent the minimum distance traveled for the amount of time-at-large, and do not account for deviations from a straight line of travel. The straight-line distance traveled from release location to sample location for CWT Chinook ranged from 12 km to 264 km in 2001, and from 12 km to 267 km in 2002. The longest minimum distance traveled for Chinook in both years resulted from fish leaving the Marblemount Hatchery on the Skagit River, and then recaptured in WRIA 8. In 2001 and 2002 the shortest minimum distance traveled was by fish released from Grover’s Creek Hatchery and recovered at Richmond Beach. In both years, the largest proportion of Chinook originated from 64 km (40 miles) to 96 km (60 miles) away from the recapture site.

3.2.1.5. Minimum Rate of Travel

The rate of travel for Chinook is based on the assumption that the fish travel in a straight line from release to recapture point. Also it is important to note that the estimated time-at-large is based on a mean release date for volitional releases (i.e., mean time for range of release dates). As a result of both of these assumptions the calculated rate of travel should be treated as a minimum. In 2001, travel rates ranged from .45 km/day (.28 mi/day) to 8.57 km/day (5.33 mi/day) and averaged 3.02 km/day (1.88 mi/day). In

2002, travel rates ranged from .42 km/day (.26 mi/day) to 25.26 km/day (15.7 mi/day) and averaged 3.83 km/day (2.38 mi/day).

3.2.2. Coho

3.2.2.1. Origin and Capture Location

Coded wire tagged coho recoveries in 2001 originated from 4 hatcheries, located in 3 different WRIAs (Table 3.15). Three of the 6 coho originated from the Wallace River hatchery. Of these, 2 were recovered in WRIA 8 and one in WRIA 9. Three of the 6 coho were recaptured at the Maury Island Park site.

Coded wire tagged coho recoveries in 2002 (45) originated from 10 hatcheries located throughout Puget Sound (Table 3.17). Six hatcheries from 6 different WRIAs were represented in the north region catch and 4 hatcheries from 3 different WRIAs were represented in the south region catch of tagged coho. However, there was no overlap of hatchery representation in the catch between the 2 regions. Most of the tagged coho were collected at the north mainland sites (32) with the majority of those originating from the Issaquah hatchery (40%), followed by fish originating from the Wallace River hatchery (18%). The second largest number of tagged coho (22%) was collected at the south mainland and island sites, which originated from the Voights Creek hatchery. The highest number of tagged coho recovered by site was from Meadowdale (29%), followed by the Picnic Point (18%) and Talequah (11%) sampling sites.

3.2.2.2. Net Direction of Travel

In 2001, only 6 CWT coho were caught throughout the study area. Four were recaptured in WRIA 9, 2 in WRIA 8. Three of the 4 recaptures in WRIA 9 were collected at the Maury Island Park site (Table 3.15). The low number of CWT coho recaptures in 2001 is due, in part, to the fact that coho were not being checked for CWTs until July. In 2002, 45 CWT coho were caught in the study area (Table 3.17). Forty percent of all CWT coho came from Issaquah Creek hatchery and were caught only at northern sample sites. Of the 11 CWT coho originating from WRIA 10, 91% were caught at sample sites on Vashon and Maury Islands. One hundred percent of the Wallace River Hatchery, Soos Creek Hatchery and Port Gamble Hatchery CWT coho were caught at north mainland sample sites.

3.2.2.3. Time-at-Large

Time-at-large for coho ranged from 7 to 183 days in 2001 and from 0 to 93 days in 2002. In 2001, recaptured CWT coho were released from April 9 through May 10th. In 2002, recaptured CWT coho were released from March 15 through June 7, though most fish were released from mid-April through early May. In 2002, 89% (n=40) of all recovered CWT coho were caught within 40 days from time of release, with the other 5 coho being at-large between 60 and 93 days.

3.2.2.4. Minimum Distance traveled

Straight line distance traveled from release location to sample location for CWT coho ranged from 58 km to 134 km in 2001, and from 12 km to 180 km in 2002. This distance includes the freshwater distance traveled from release point.

3.2.2.5. Minimum Rate of Travel

In 2001, the rate of travel ranged from .32 km/day (.2 mi/day) to 9.14 km/day (5.68 mi/day), with an average of 2.22 km/day (1.38 mi/day). In 2002, the rate of travel ranged from .76 km/day (.47 mi/day) to 11.13 km/day (6.92 mi/day), with an average of 3.15 km/day (1.96 mi/day).

3.2.3. Estimated Growth

In general, juvenile Chinook sizes were most frequent in the range of 70 to 100 mm early in the sampling period and shifted to larger size classes later in the sampling season. A subsample of CWT hatchery Chinook were used to estimate growth, based on the estimated length and/or weight at release data (i.e., group mean values) provided by the hatcheries (www.rmis.org) and the length and/or weight data collected upon recapture. Of the 86 Chinook measurements (FL) used in 2001, 19 (22%) showed negative growth and 67 (78%) showed positive growth (Table 3.19). Eleven (16%) of the 67 Chinook exhibiting positive growth were from the Soos Creek hatchery. However, 18 (95%) of the 19 fish exhibiting negative growth originated from the Soos Creek hatchery (Table 3.19). Similarly, of the 97 CWT Chinook evaluated for growth in 2002, 23 (24%) showed negative growth, while 70 (72%) exhibited positive growth. When evaluating growth by weight (g) of 107 CWT recaptured Chinook, 10 (9%) exhibited negative growth and 97 (91%) exhibited positive growth. Again, the fish from the Soos Creek Hatchery exhibited a very high percentage of zero, or negative growth in length (25 out of 32 fish, or 78%) and weight (41% showed a decrease in weight) from the time of release to recapture (Table 3.19).

Table 3.19. Estimated growth of Coded Wire Tagged Chinook in 2001 and 2002 compared to Soos Creek Hatchery.

	Total All Hatcheries				From Soos Creek Hatchery			
	2001		2002		2001		2002	
	#	%	#	%	#	% of all CWT fish	#	% of all CWT fish
Negative growth by length	19	22%	23	24%	18	95%	21	91%
0 growth by length	0	0	4	4%	0	0	4	100%
Positive growth by length	67	78%	70	72%	11	16%	7	10%
Negative growth by weight			10	9.3%			7	70%
0 growth by weight			0	0			0	0
Positive growth by weight			97	90.7%			10	10.3%

3.3. DIETARY ANALYSIS

Stomach contents of 819 juvenile Chinook salmon, 89 juvenile coho salmon, and 56 cutthroat trout collected in 2001 and 2002 were analyzed by staff in the Wetland Ecosystem Team (WET) at the University of Washington. Samples were collected from 12 sites in 2001 and 14 sites in 2002 (Table 3.20). Sites were grouped into 3 regional categories for comparison and classified as North Mainland (Picnic Point, Meadowdale, Ocean Ave, Edmonds, Richmond, Carkeek Park and Golden Gardens), South Mainland (Lincoln Park, Seahurst Park and Marine View Park), or Vashon/Maury Island (Maury Island Park, Burton Park, Pt. Robinson, Camp Sealth, DNR Beach 83 and Pt. Heyer or KVI).

Unless otherwise noted, graphical representation of the diet data is presented as percent gravimetric (weight) composition. This metric was chosen as the most accurate reflection of prey contribution in terms of energy, because in many cases prey that was quite numerous (e.g., small insects) had low biomass and presumably relatively low caloric contribution, as compared to less numerically abundant but heavy prey (e.g., polychaetes, fish).

3.3.1. Chinook Salmon

A total of 819 juvenile Chinook salmon diet samples from 16 beaches were analyzed, including 410 individuals from 2001 and 409 from 2002 (Table 3.20; Appendix 4). The size range of fish analyzed for diets was quite large, from 70-354 mm FL (Figure 3.26). The size class analysis showed the presence of at least three distinct size groups of fish (Figure 3.26).

Table 3-20. Numbers, locations, and dates of all juvenile salmon analyzed for diet contents.

		Chinook		Coho		Cutthroat	
Region	Site	2001	2002	2001	2002	2001	2002
North	Picnic Pt	16	1	4	8	12	
	Meadowdale	31	3	5	10	12	8
	Oceanview	21		2			
	Edmonds		2		5		
	Richmond	24	56	7	4		
	Carkeek	22	30	5	2	1	
	Golden Gardens	13	40	2	1	2	
South	Lincoln	65	89	1	1	3	
	Seahurst	64	26	14		8	
	Marineview	34		6		6	
Island	Burton	32	2			1	
	Camp Sealth		9				1
	DNR		20				
	KVI	42	41	3		2	
	Maury Is	46	68	2	7		
	Pt Robinson		22				
	Total	410	409	51	38	47	9

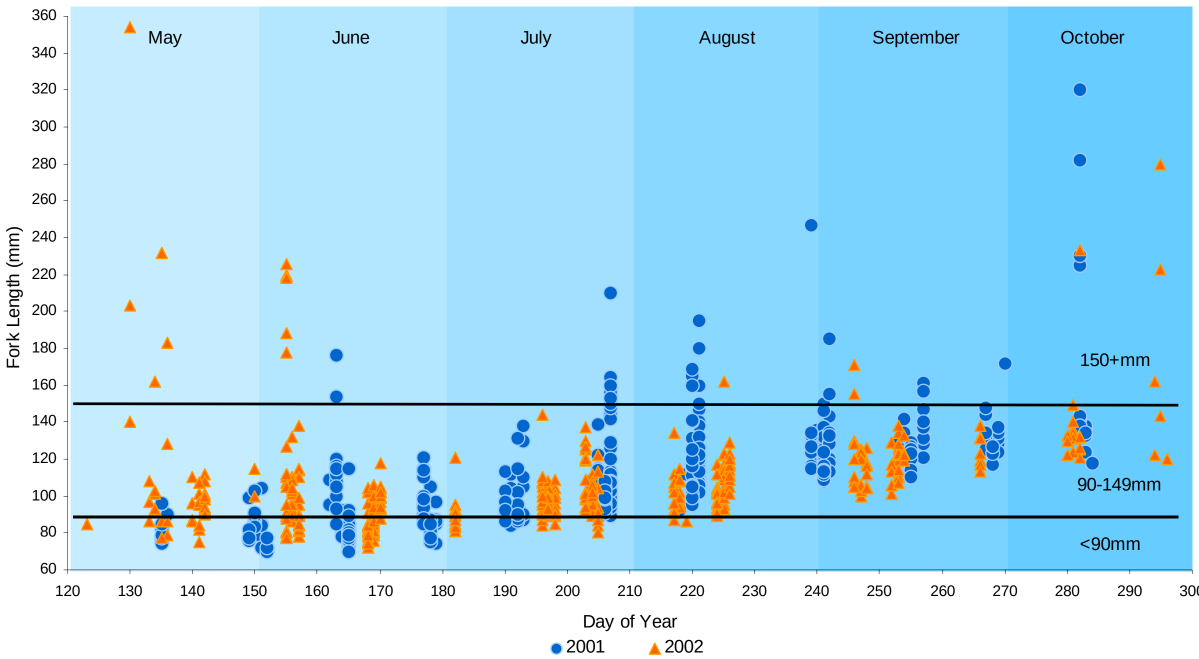


Figure 3.26. Fork-lengths of juvenile Puget Sound Chinook salmon collected in 2001-2002 and analyzed for diets. Size classes that were grouped for further analyses are indicated in the figure.

3.3.1.1. Overall Diet Composition

In both 2001 and 2002, terrestrial insects, especially *psocoptera* (bark lice), *aphididae* (aphids), *chironomidae* (midges), and formicidae (ants) (Figures 3.27 and 3.28) numerically dominated Chinook diets. Plant matter and barnacle exuviae (shed exoskeletons) had high frequencies of occurrence in both years in Chinook diets, but contributed relatively little to prey numbers or weights. In both years gravimetric composition was dominated by fishes, including sand lance (*Ammodytes hexapterus*), herring (*Clupea pallasi*), and perches (*embiotocidae*). Two taxa, the polychaete worm *Platynereis bicanaliculata* and hyperiid amphipods, had relatively high gravimetric and numerical compositions in both years (Figures 3.27 and 3.28). Megalopae of crabs of the genus *Cancer* were similarly important in 2002 (Figure 3.28).

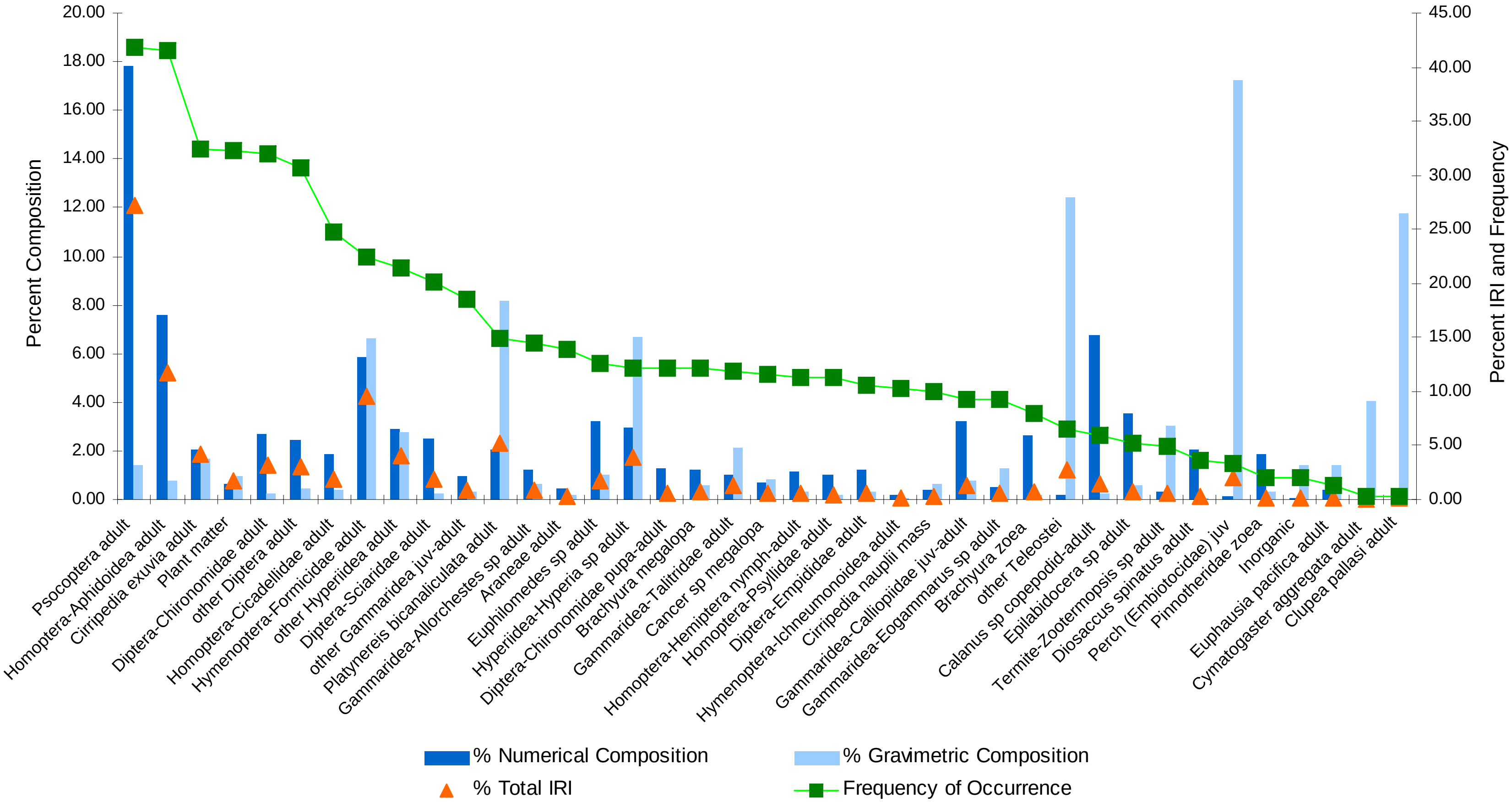


Figure 3.27. Overall diet composition (gravimetric, numerical, frequency of occurrence, IRI value) of juvenile Puget Sound Chinook salmon collected in 2001. Taxa with a frequency of occurrence less than ten and numerical and gravimetric compositions both less than one are excluded from the figure.

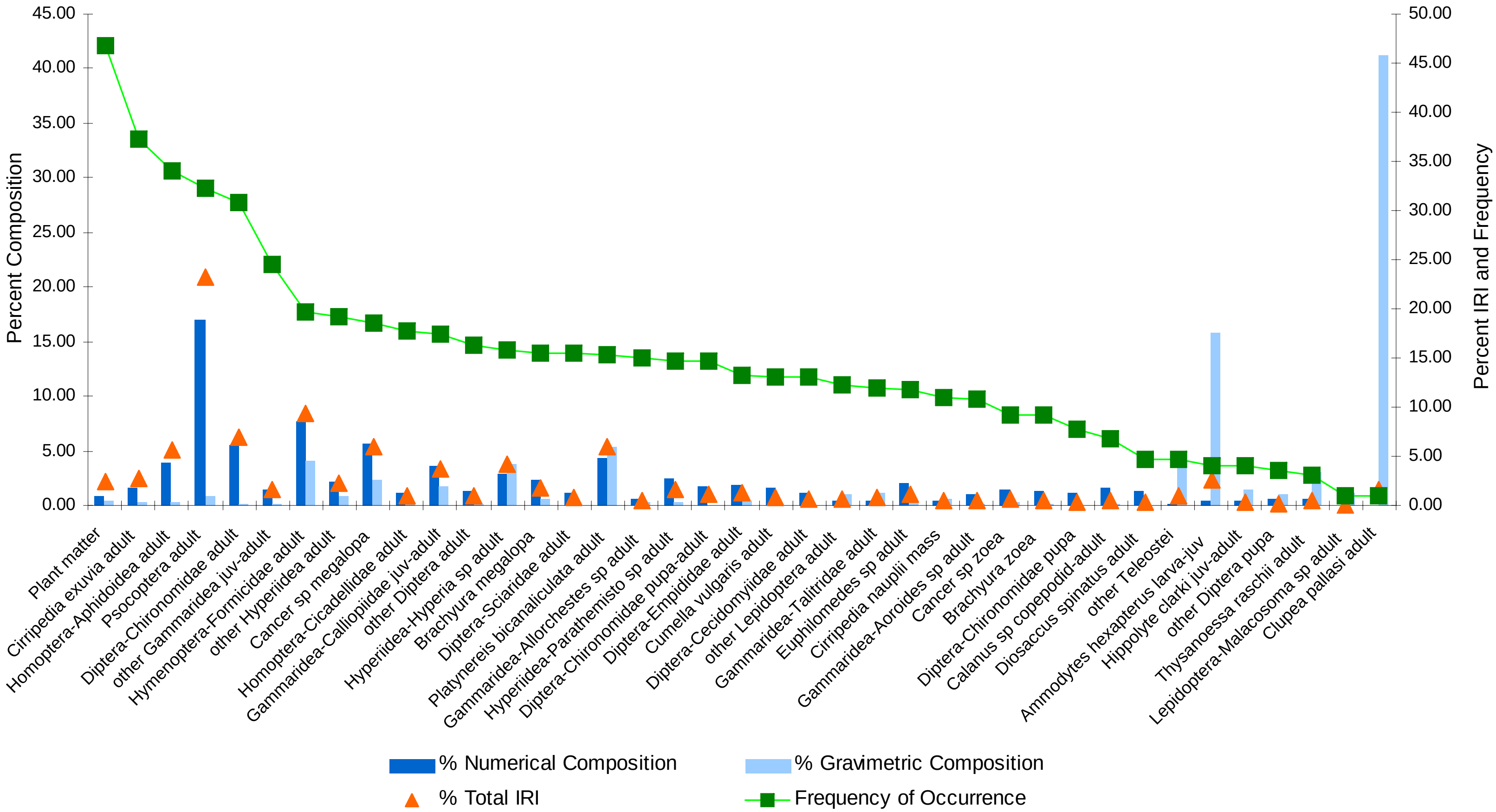


Figure 3.28. Overall diet composition (gravimetric, numerical, frequency of occurrence, IRI value) of juvenile Puget Sound Chinook salmon collected in 2002. Taxa with a frequency of occurrence less than ten and numerical and gravimetric compositions both less than one are excluded from the figure.

Numerical composition of Chinook diets was very similar between 2001 and 2002, with terrestrial/riparian taxa dominating the diet, followed by marine planktonic/neritic and marine benthic/epibenthic categories (Figure 3.29). In gravimetric composition, overall diets were also similar between years, with marine planktonic/neritic prey dominant, followed by marine benthic/epibenthic and terrestrial/riparian prey. Prey from supralittoral/marsh and other habitats formed only a minor constituent of the diet by number and weight.

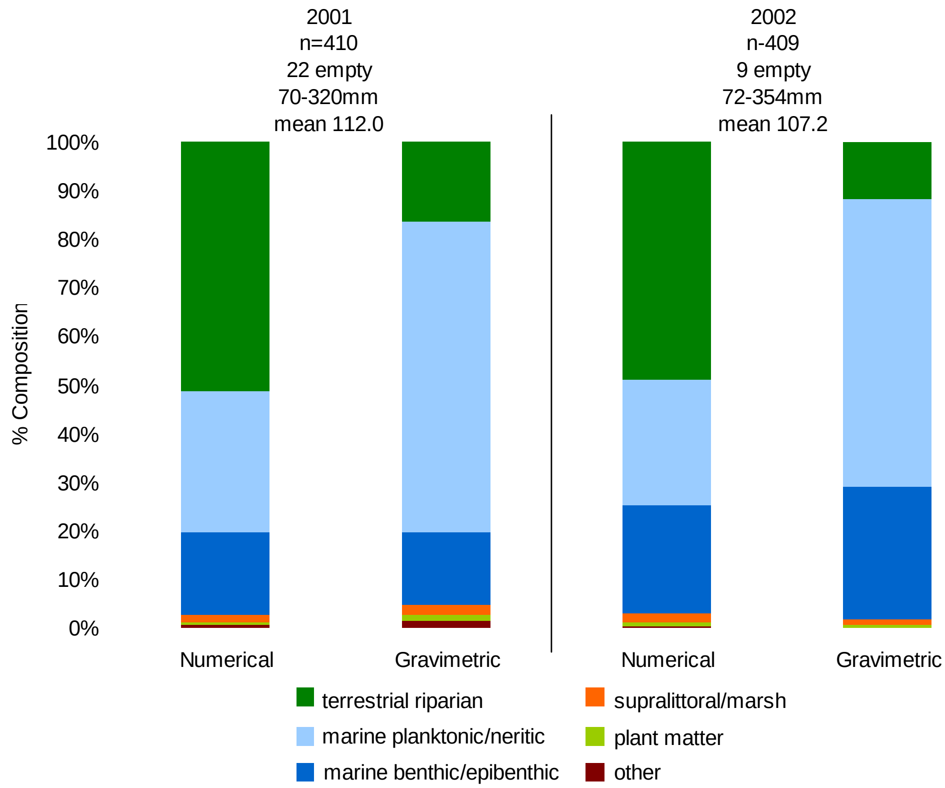


Figure 3.29. Overall diet composition by weight based on prey ecology for juvenile Puget Sound Chinook salmon from 2001-2002.

3.3.1.2. Diet by Size Class

For juvenile Chinook salmon in the smallest size class examined (<90 mm), diets were made up mostly of benthic/epibenthic prey (Figure 3.30). Chinook in the next three size classes, spanning 90-149 mm had diet contents that were more evenly distributed into three ecological categories—benthic/epibenthic, planktonic/neritic, and terrestrial/riparian. In 2001 fish in these three size classes consumed progressively more terrestrial/riparian prey and less benthic/epibenthic prey as the size classes became larger. However, this was not the case in 2002, where proportionally more benthic/epibenthic prey were consumed in the 130-149 mm size class. Terrestrial/riparian diet components were prominent (~50% of prey weight) in both years in the two middle size classes that included fish from 110-149 mm. The two largest size classes fed mainly in the water column on planktonic/neritic prey, with the exception of the 150-169 mm size range in 2002, which had about 50% of the prey weight represented by benthic/epibenthic prey taxa (Figure 3.30). In all size groups, only minor contributions to the diets were made by supralittoral/marsh organisms and plant material.

In data broken down by prey taxonomic groups, the gravimetric composition of the smallest juvenile Chinook salmon size class (<90 mm) was dominated by polychaete worms[1] in both years (Figure 3.31). In the next three size classes, gravimetric composition of prey was more diverse and distributed into several taxonomic categories. These included hyperiid and gammarid amphipods, shrimp-like taxa[2], polychaete worms, larvae of decapod crustaceans, hymenopteran and other insects, and fishes. In the largest of these three size classes (i.e., 130-149 mm), Hymenoptera and “other” insects and fish were especially important in 2001, while gammarid amphipods showed higher percent gravimetric composition for this size range in 2002 (Figure 3.31). In the two largest size classes, fish made up the majority of the prey, except for the 150-169 mm category in 2002, in which a small group of fish (n=4) had diets dominated by shrimp-like taxa and polychaete worms.

3.3.1.3. Diet by Month

In May 2001, polychaete worms dominated both the <90 and 90-149 mm size classes of juvenile Chinook salmon, making up 60-80% of the prey weight (Figure 3.32). In June, the <90 mm size class diets were also dominated by polychaetes, but the 90-149 mm size class had prey distributed into a number of categories, including dipteran flies, decapod larvae, and a category made up of a variety of “other” taxa. Gammarid amphipods dominated the diet of Chinook <90 mm in July, and prey in the 90-149 mm size class were distributed into 4 main taxa groups, including fishes, amphipods, shrimp-like taxa, and gammarid amphipods. July diets for Chinook >150 mm were made up of fish. In August through October, Chinook <90 mm did not occur, and the smallest size class consisted of fish 90-149 mm. August diets for this size class were very diverse: a variety of insect taxa comprised about 40% of the prey weight, with smaller contributions by hyperiid and gammarid amphipods, barnacle exuviae and eggs, fish, and polychaetes. Chinook in the >150 mm size class fed almost exclusively on fish in August. In September, insects made up over 50% of the prey weight in Chinook from the 90-149 mm and over 80% of the >150 mm size classes. In both size classes the largest groups of insects represented in the prey weight were psocoptera and a category of “other” insect taxa. October diets for the 90-149 mm size class were primarily made up of three main categories, including hyperiid amphipods, gammarid amphipods,

[1] Polychaete worms were dominated by one species, *Platynereis bicanaliculata*, which made up about 95% of both count an weight of the Polychaeta category for both years combined.

[2] Unless otherwise noted, shrimp-like taxa in diets were dominated by euphausiids, especially the species *Thysanoessa raschii*.

and exuviae and eggs of barnacles, followed by insect taxa (combined). The >150 mm size class consumed fish, with a small component of the diet represented by hyperiid amphipods.

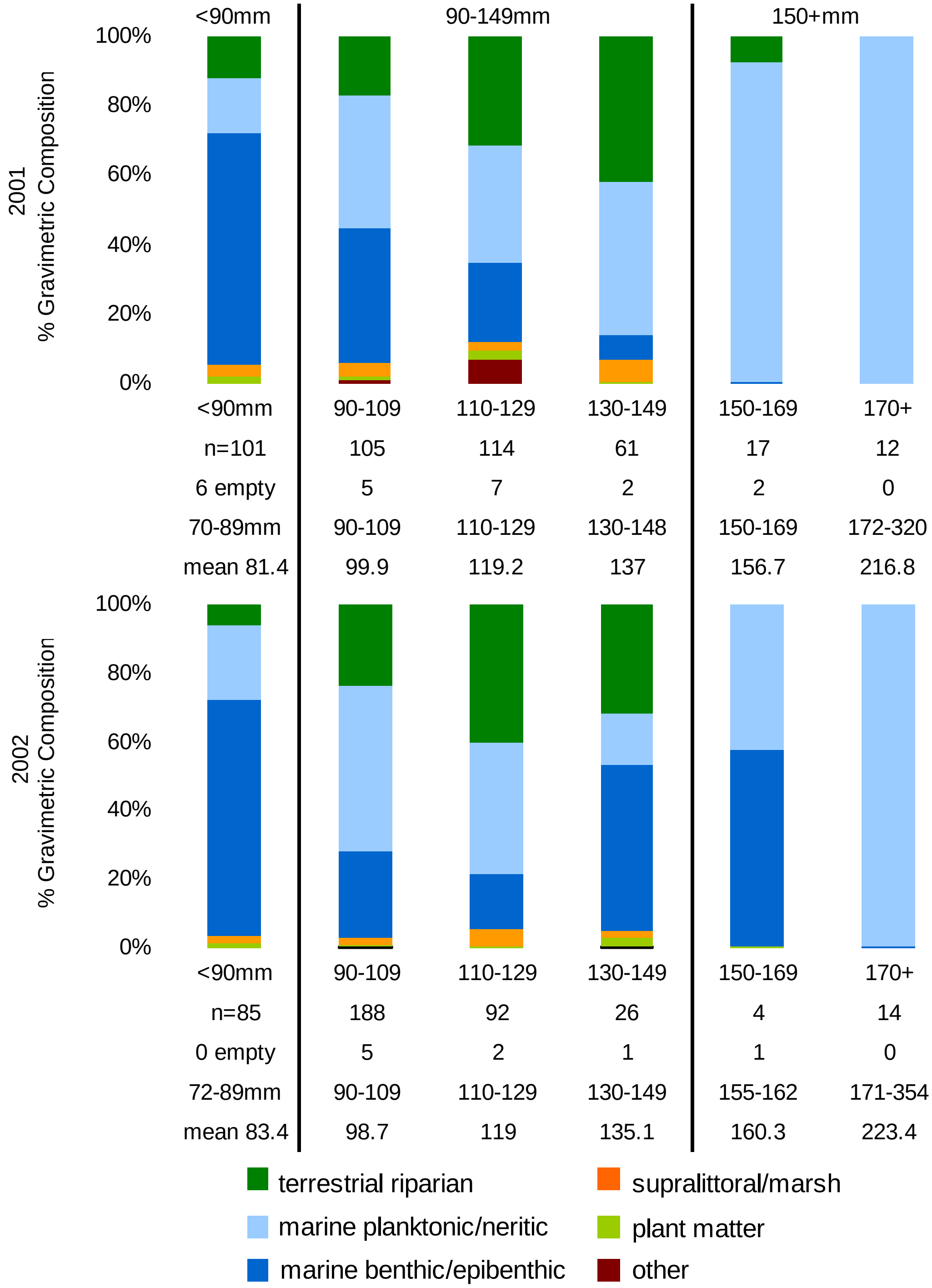


Figure 3.30. **Diet composition by weight based on prey ecology for six size classes of juvenile Puget Sound Chinook salmon from 2001 and 2002.**

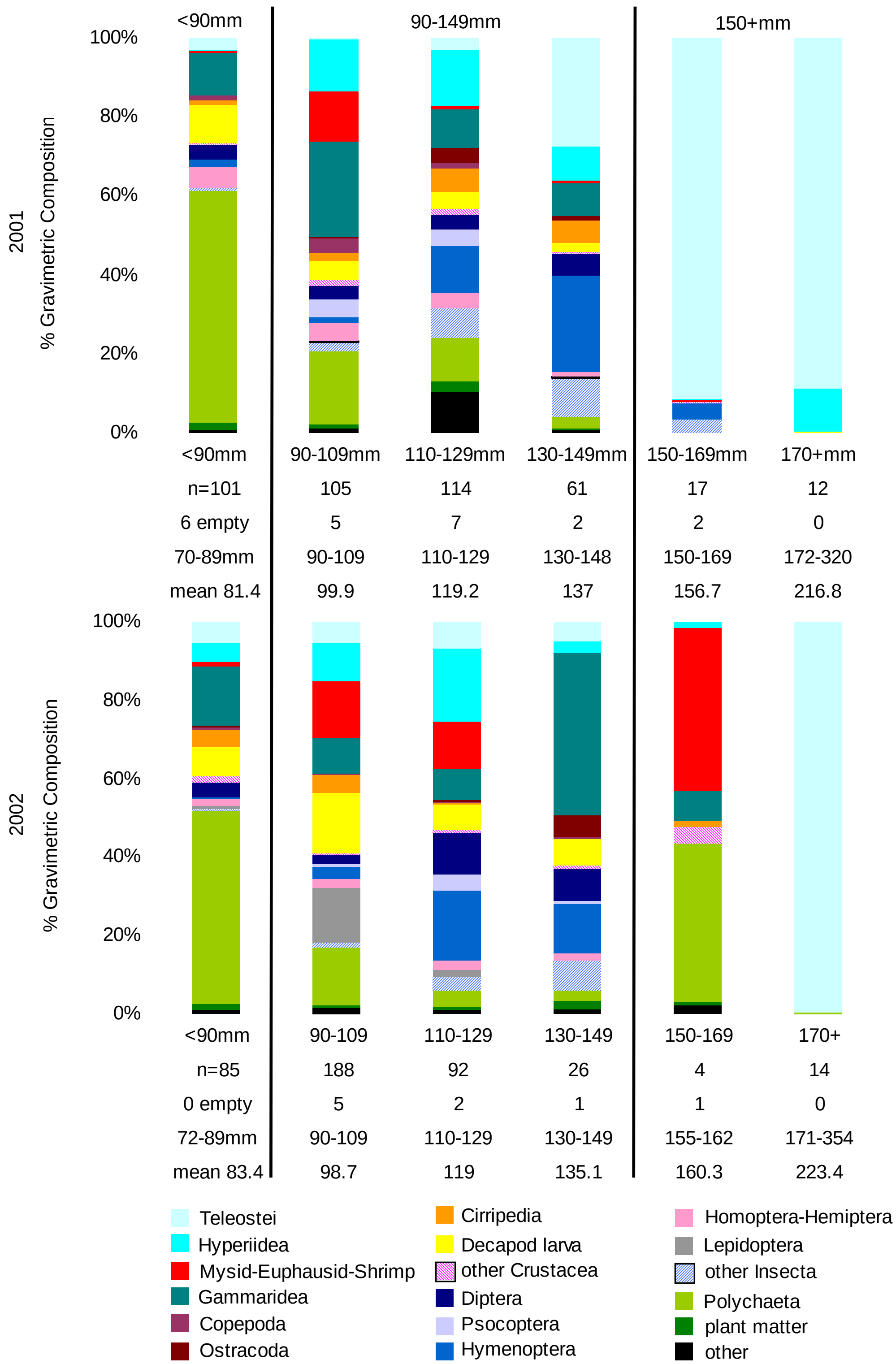


Figure 3.31. Diet composition by weight based on taxonomic groups for six size classes of juvenile Puget Sound Chinook salmon from 2001 and 2002.

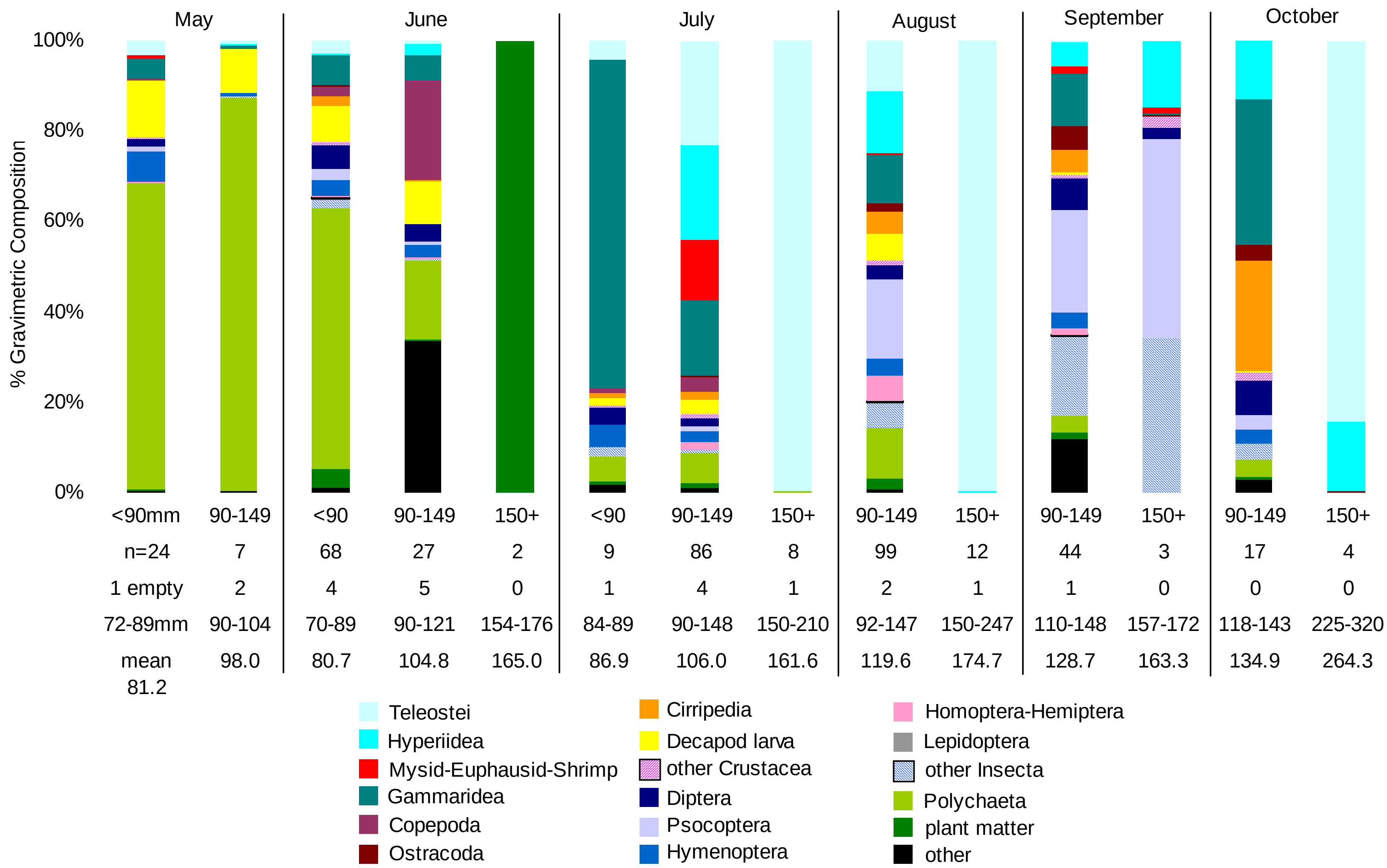


Figure 3.32. Diet composition by weight based taxonomic groups for three size classes of juvenile Puget Sound Chinook salmon in five time periods in 2001.

In 2002, fish dominated diets of the >150 mm size class of juvenile Chinook salmon in each month (Figure 3.33). In May 2002, juvenile Chinook salmon in the <90 mm size class consumed mostly fish and gammarid amphipods (combined, >50% of prey weight), with smaller contributions from decapod larvae and exuviae and eggs of barnacles. Diet in the 90-149 mm size class was made up mostly of shrimp-like taxa (>60% of prey weight), followed by fishes and exuviae and eggs of barnacles. In June, diets of Chinook <90 mm were similar to those for May-June 2001, being dominated by polychaete worms. The 90-149 mm size class had approximately equal diet contributions by decapod larvae and polychaetes, with a small contribution by other taxa. As in 2001, juvenile Chinook prey in July began to be distributed into a larger number of taxa groups. Chinook <90 mm caught in July fed mainly on three taxa—hyperiid amphipod, gammarid amphipods, and polychaetes (>60% of prey weight in aggregate)—followed by a variety of other prey. For fish in the 90-149 mm size class, diets were unique in being dominated by lepidopteran insects [3] (~50% of prey weight; ~60% insects by weight in aggregate), with the remainder of the prey represented mostly by gammarid amphipods and decapod larvae. In August, the small sample (n=3) of Chinook <90 mm fed on four main prey groups, including shrimp-like crustaceans (caridean shrimp), hyperiid amphipods, gammarid amphipods, and polychaetes. For diets of fish 90-149 mm, prey weight was dominated by hyperiid amphipods (~50%), followed by a variety of insect taxa (~25% of prey weight in aggregate). September diets of Chinook in the 90-149 mm size class were dominated by hymenopterans and a diverse assemblage of other insect taxa (>50% of prey weight taken together). This was also the case for Chinook in the same size class in October, in which prey was divided approximately equally between gammarid amphipods and insects (mostly dipterans).

3.3.1.4. Diet by Location

In terms of ecological prey groupings, results for data based on geographical location were similar in 2001 and 2002 (Figure 3.34). Small Chinook salmon in the <90 mm size class fed primarily on benthic/epibenthic prey in both years, except at the northern sites, for which prey was about equally distributed into benthic/epibenthic and planktonic/neritic groups. Terrestrial/riparian prey was of lesser importance for the <90 mm size class, and was highest in percent gravimetric composition at the northern sites and lowest at the Vashon/Maury Island sites in both years. For the 90-149 mm size class, there were no striking differences among site groupings in either year, and prey was distributed more evenly into terrestrial riparian, benthic/epibenthic and planktonic/neritic prey groups. However, this size class showed the highest composition of insects in their diet. Fish dominated the diets at all of the sites for the largest size class of Chinook, except at the northern sites in 2001, when a small group (n=4) of fish were feeding on plant matter.

For diet composition of Chinook at different locations, broken down by taxa group, polychaetes dominated the prey of fish <90 mm at all of the site groupings in both 2001 and 2002 (Figure 3.35). In both years, the smallest diet proportion of polychaetes in the diets of these fish occurred at the northern sites, where gammarid amphipods, decapod larvae, and a variety of terrestrial insects were more important than at the other two site groupings. For the 90-149 mm size class, prey was distributed into many taxa groups, and there did not appear to be any large differences among the area groupings that were consistent between years. In most cases, prey for these fish consisted mainly of terrestrial insects. There was a difference in composition of these insects in the diet between years, with hymenoptera and homoptera/hemiptera more prominent in 2001 and psocoptera and diptera more prominent in 2002. Lepidoptera were abundant in diets only in 2002.

[3] Lepidoptera in 2002 diets were gravimetrically dominated by tent caterpillar moths, *Malacosoma* sp. (51% of Lepidoptera category by weight).

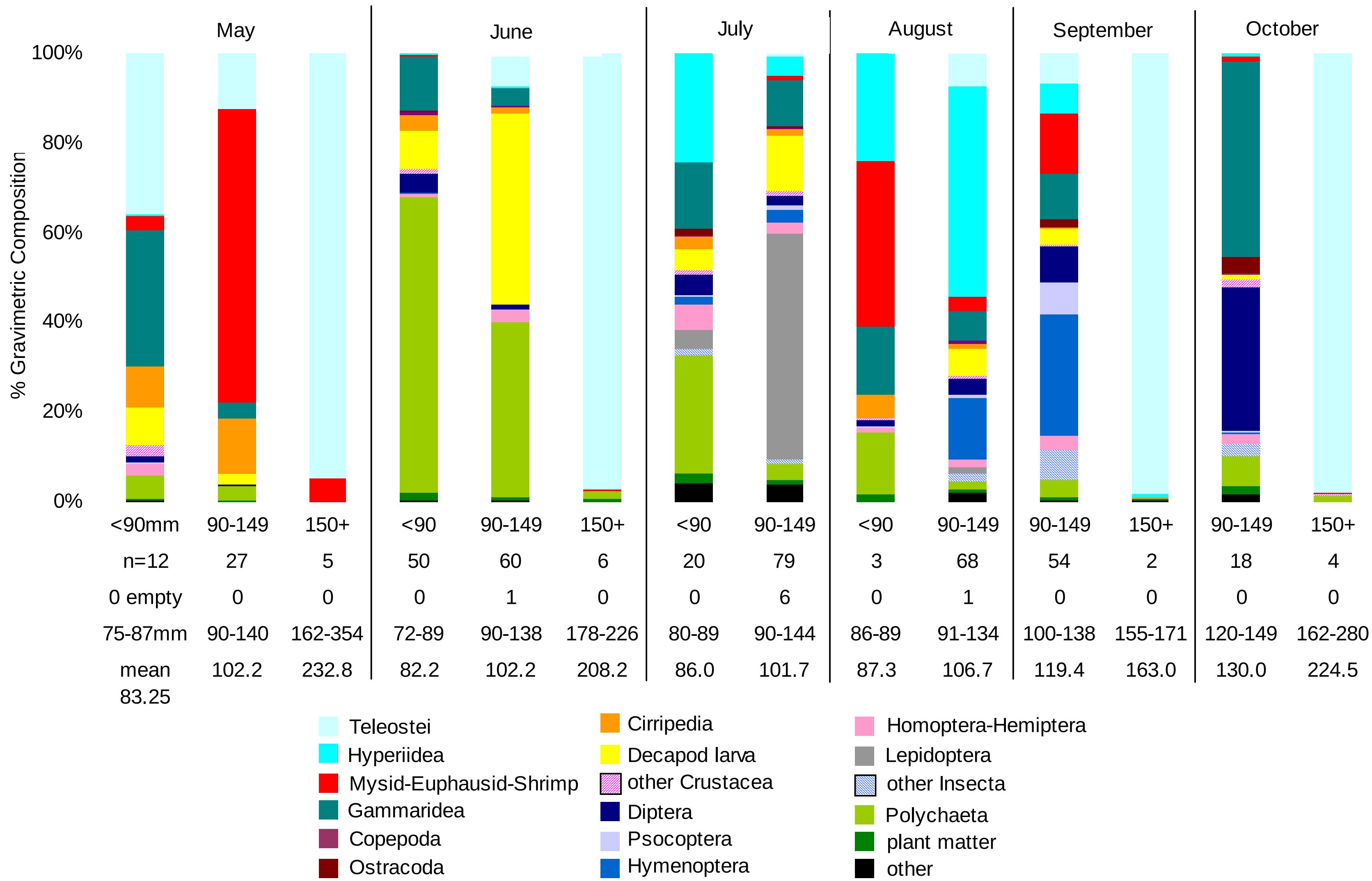


Figure 3.33. **Diet composition by weight based taxonomic groups for three size classes of juvenile Puget Sound Chinook salmon in five time periods in 2002.**

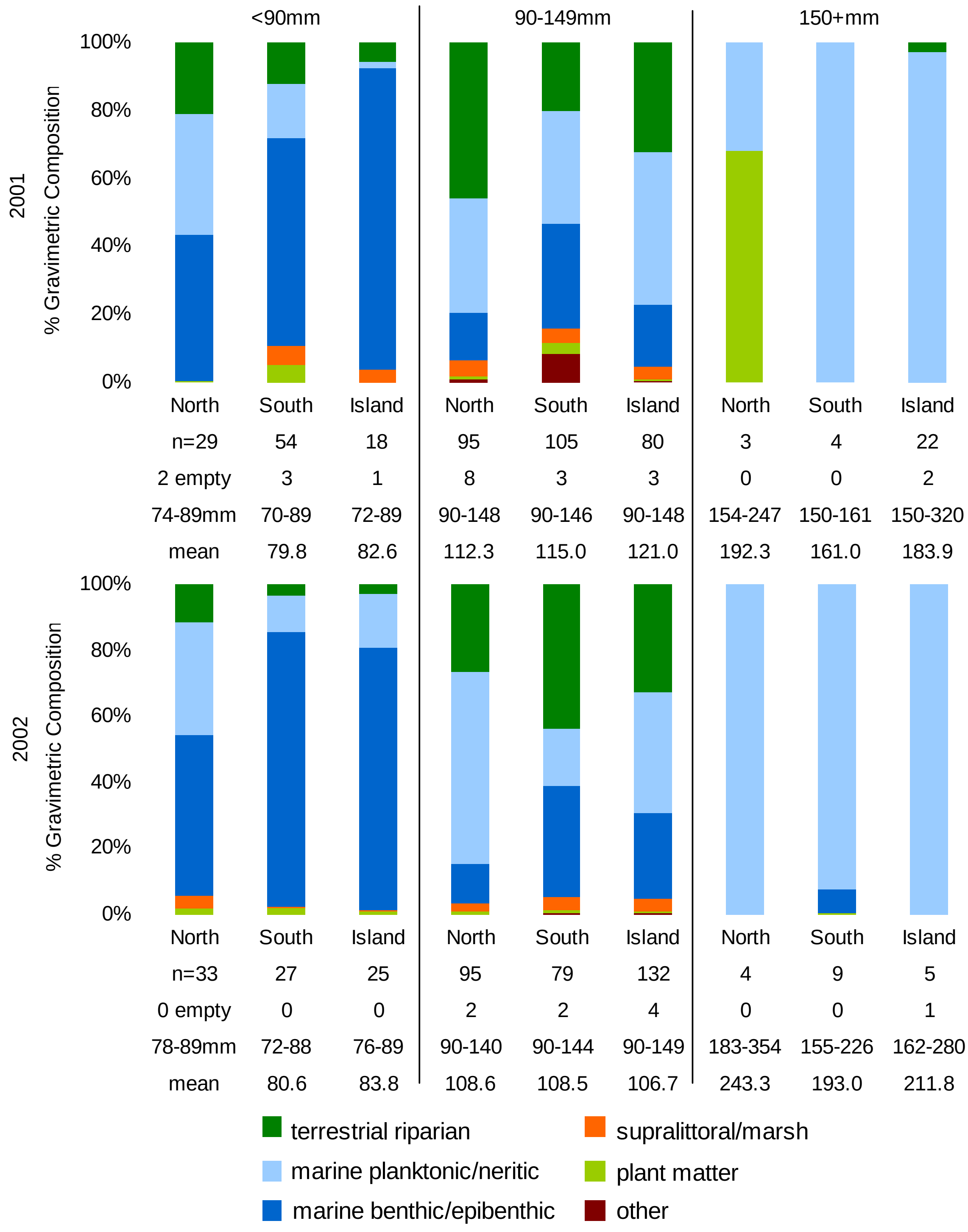


Figure 3.34. Diet composition by weight based on prey ecology and geographic region for three size classes of juvenile Puget Sound Chinook salmon from 2001 and 2002.

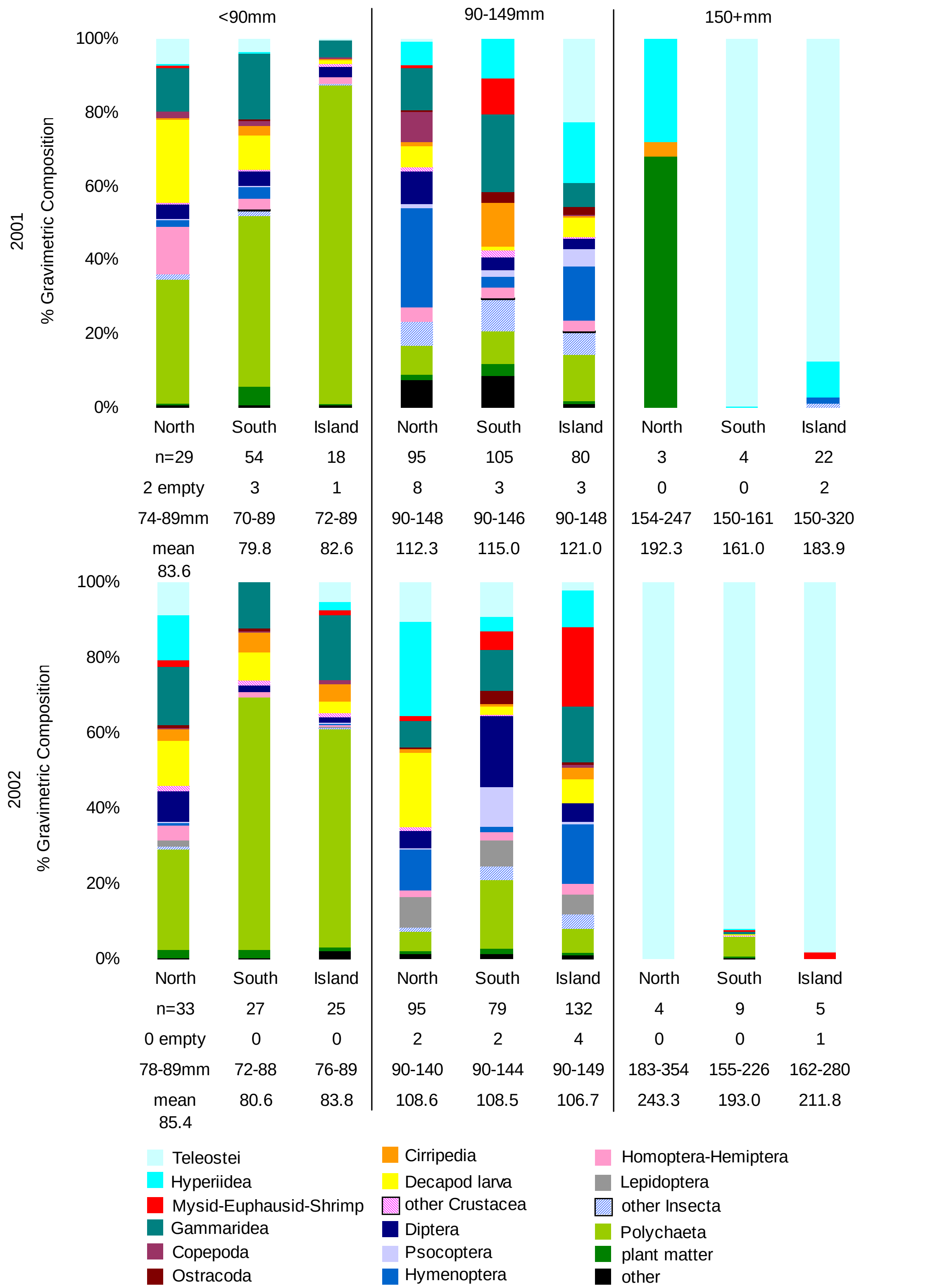


Figure 3.35. Diet composition by weight based on prey taxonomic groups and geographic region for three size classes of juvenile Puget Sound Chinook salmon from 2001 and 2002.

3.3.1.5. Hatchery versus “wild” Chinook

A preliminary analysis of data from hatchery and “wild” Chinook captured[4] in 2002[5], was broken down by month (Figure 3.36). For prey taxa groups, percent composition based on prey weight were quite similar in all months except May, when hatchery Chinook consumed more shrimp-like taxa (in this case the euphausiid *Thysanoessa raschii*) and barnacle exuviae, and “wild” fish consumed more gammarid amphipods. This was also reflected in data analyzed by prey ecology categories (Figure 3.37); hatchery fish in May had a larger proportion of planktonic prey, and wild fish had more epibenthic prey. Otherwise, prey composition based on ecological categories was similar.

3.3.2. Coho Salmon

A total of 89 juvenile coho salmon diets from 12 beaches were analyzed including 51 individuals from 2001 and 38 from 2002 (Table 3.20; Appendix 4). The size of fish ranged from 81-390 mm FL, and four size classes of coho were analyzed (Figure 3.38).

[4] For this analysis, only fish <150mm were analyzed, in order to remove those fish that were predominantly piscivorous, and improve resolution of the data.

[5] We chose 2002 for this analysis because of inconsistencies in data collection in 2001 made determination of hatchery or wild difficult.

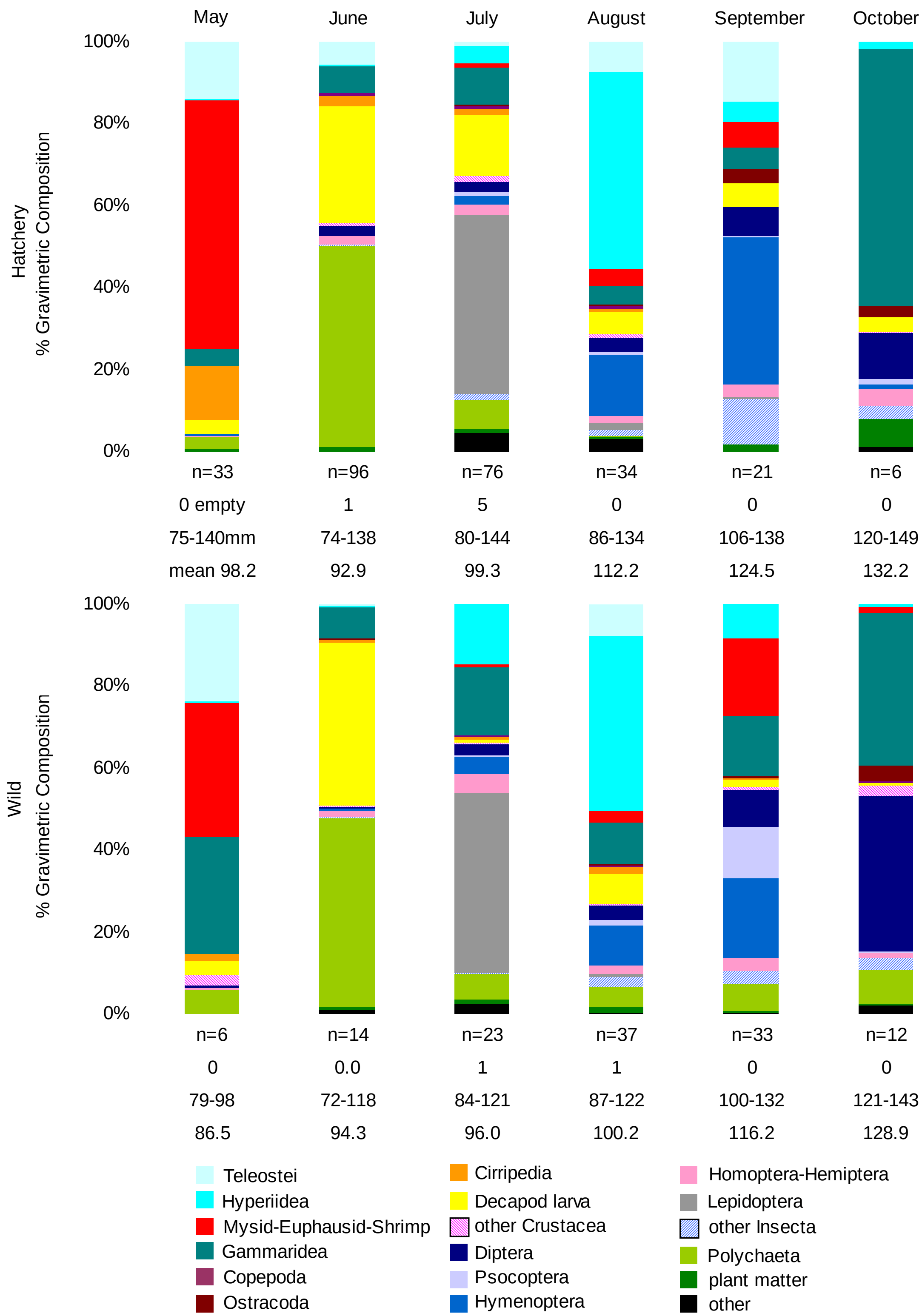


Figure 3.36. Diet composition by weight based on prey taxonomic groups for juvenile hatchery and wild Puget Sound Chinook salmon (<150mm) in 2002.

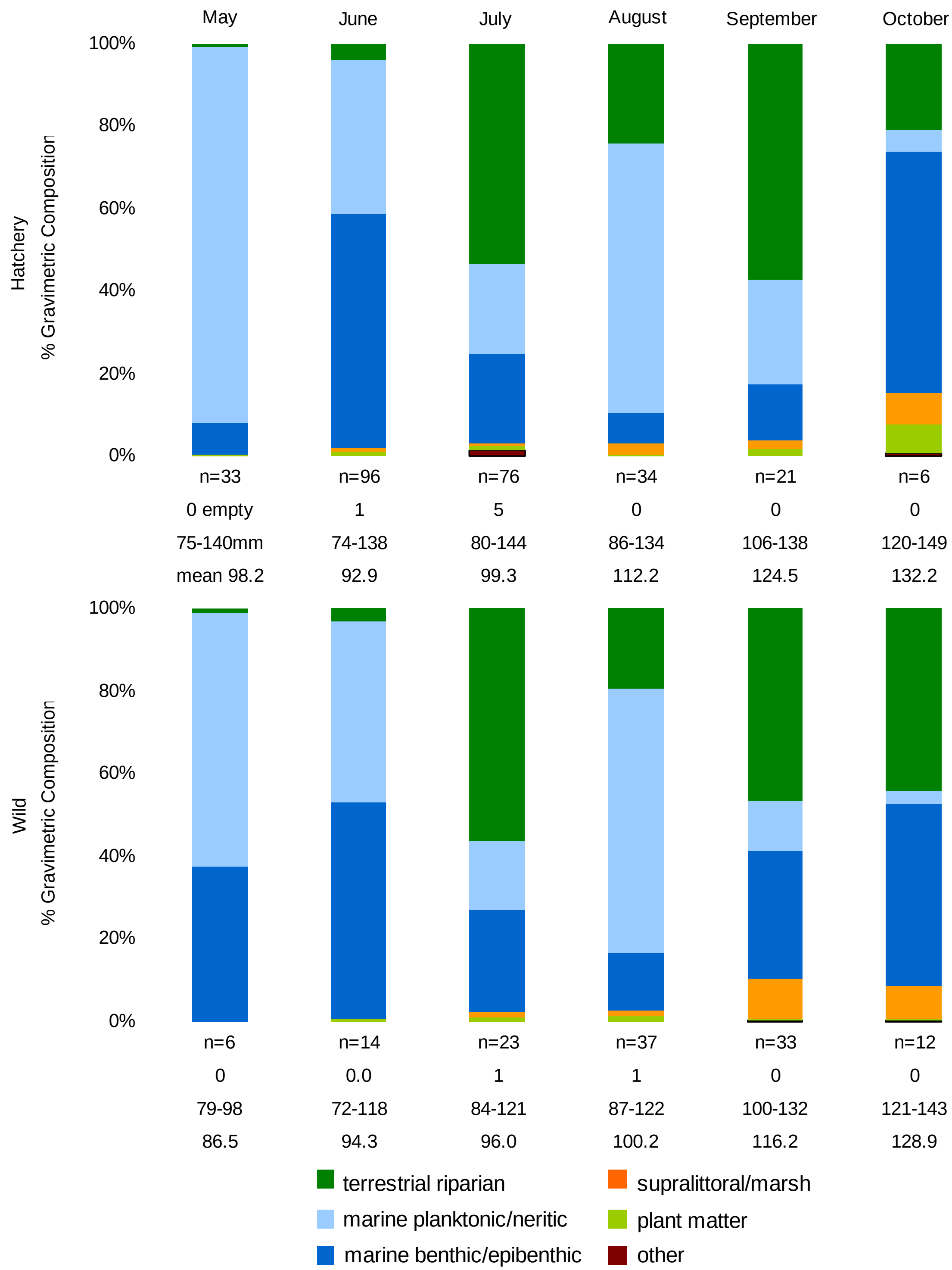


Figure 3.37. Diet composition by weight based on prey ecology for juvenile hatchery and wild Puget Sound Chinook salmon (<150mm) in 2002.

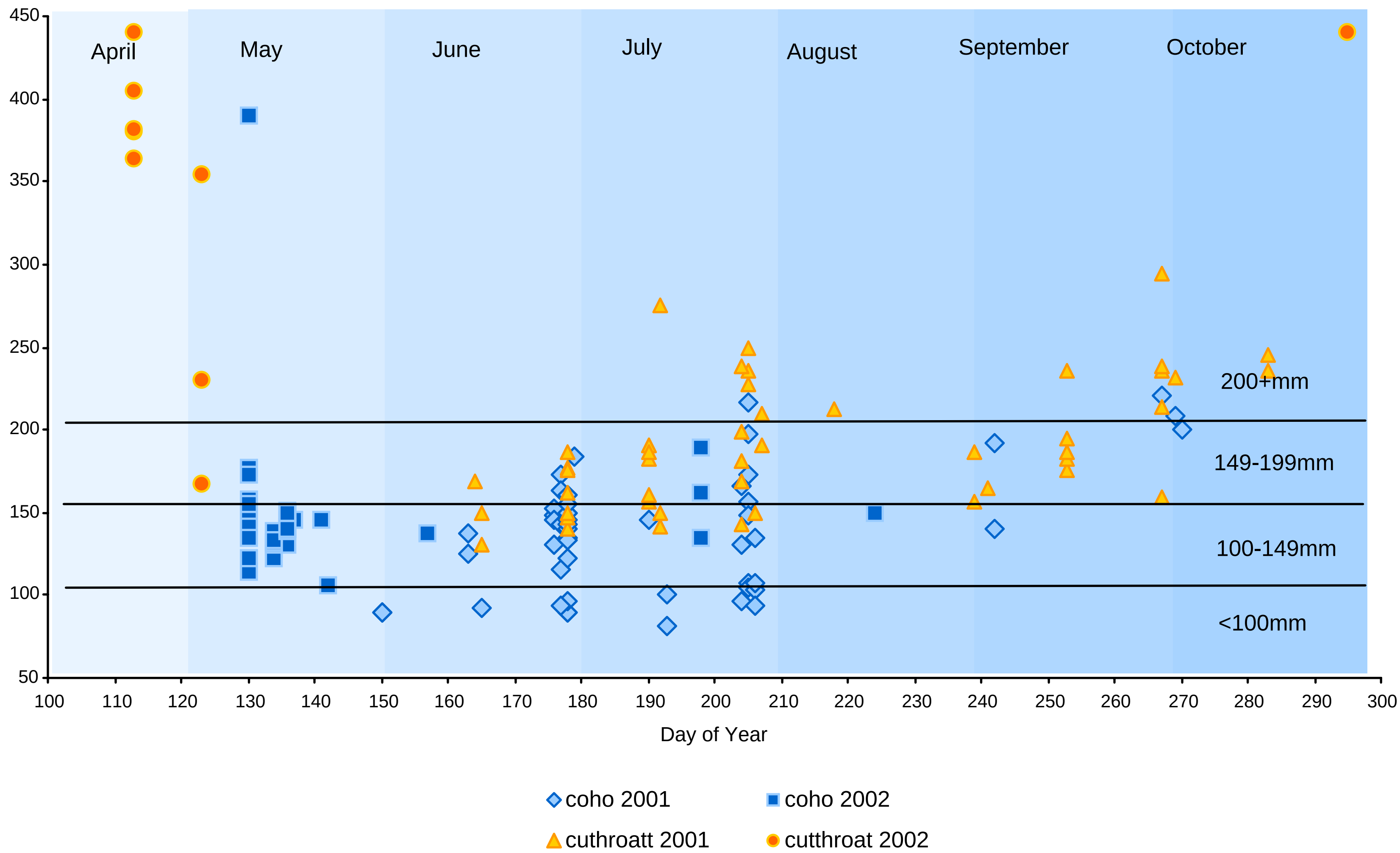


Figure 3.38. Fork-lengths of juvenile Puget Sound coho salmon and cutthroat trout collected in 2001-2002 and analyzed for diets. Size classes that were grouped for further analyses are indicated in the figure.

3.3.2.1. Overall Diet Composition

In both 2001 and 2002, coho diets were numerically composed mainly of plankton, mostly made up of *Cancer* spp. and other crab larvae, copepods, and hyperiid amphipods (Figures 3.39 and 3.40). Barnacle exuviae had very high frequency of occurrence in the diets in 2001, but comprised little of the gravimetric or numerical composition of the diets. Similarly, in 2002, *Cancer* and other crab zoeae had high frequency of occurrences but low overall weight. Prey weight of juvenile coho salmon was made up primarily of fishes, especially larval and juvenile sand lance (*Ammodytes hexapterus*) in 2002. The euphausiid *Thysanoessa raschii* also had relatively high weights in coho diets from 2002 (Figure 3.40). For coho diet data analyzed by ecological categories, planktonic/neritic prey largely dominated the diets by both numerical and gravimetric composition in both years (Figure 3.41).

3.3.2.2. Diet by Size Class

For the smallest size class of coho salmon (<100 mm), which occurred in the samples only in 2001, prey weight consisted of mostly decapod larvae (Figure 3.42). For fish in the 100-149 mm size class, prey was distributed into a variety of groups in 2001, with copepods, decapod larvae, plant material, and “other” taxa contributing about equally. In 2002 prey was made up mostly of euphausiids and fish. Diets of coho salmon in the two largest size classes, those larger than 150 mm, were dominated in both years by fish.

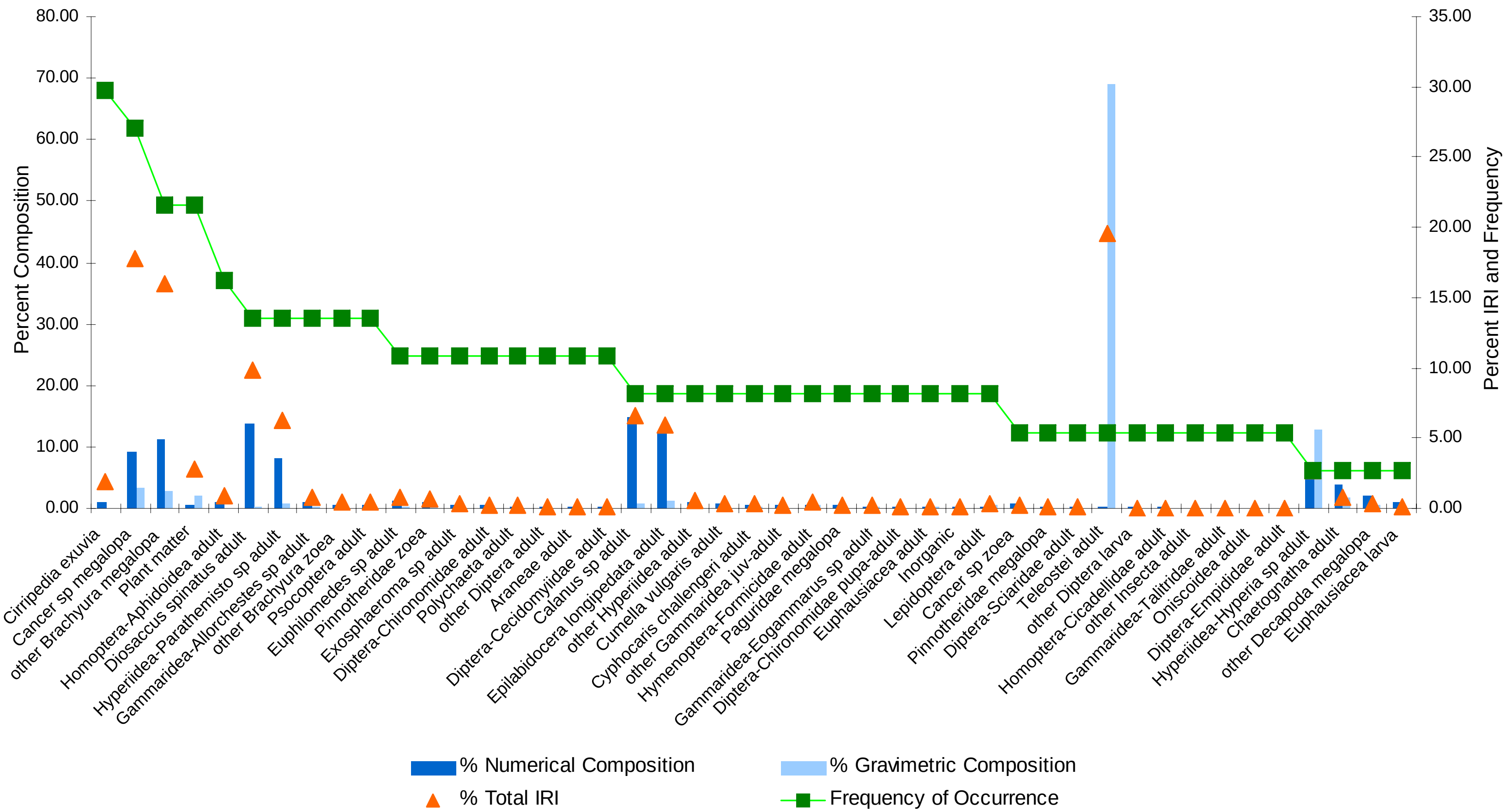


Figure 3.39. Overall diet composition (gravimetric, numerical, frequency of occurrence, IRI value) of juvenile Puget Sound coho salmon collected in 2001. Taxa with a frequency of occurrence less than five and numerical and gravimetric compositions both less than one are excluded from the figure.

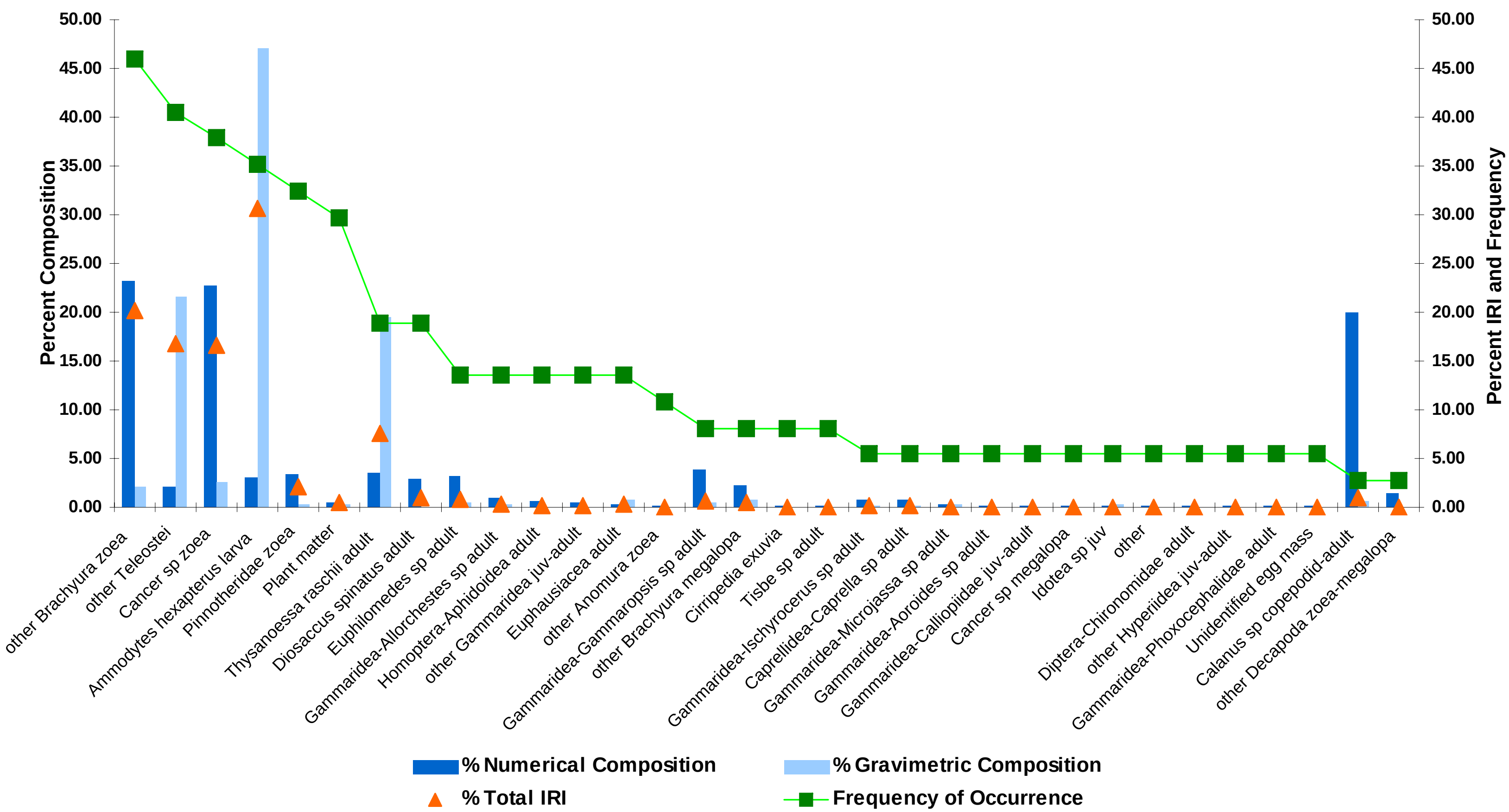


Figure 3.40. Overall diet composition (gravimetric, numerical, frequency of occurrence, IRI value) of juvenile Puget Sound coho salmon collected in 2002. Taxa with a frequency of occurrence less than five and numerical and gravimetric compositions both less than one are excluded from the figure.

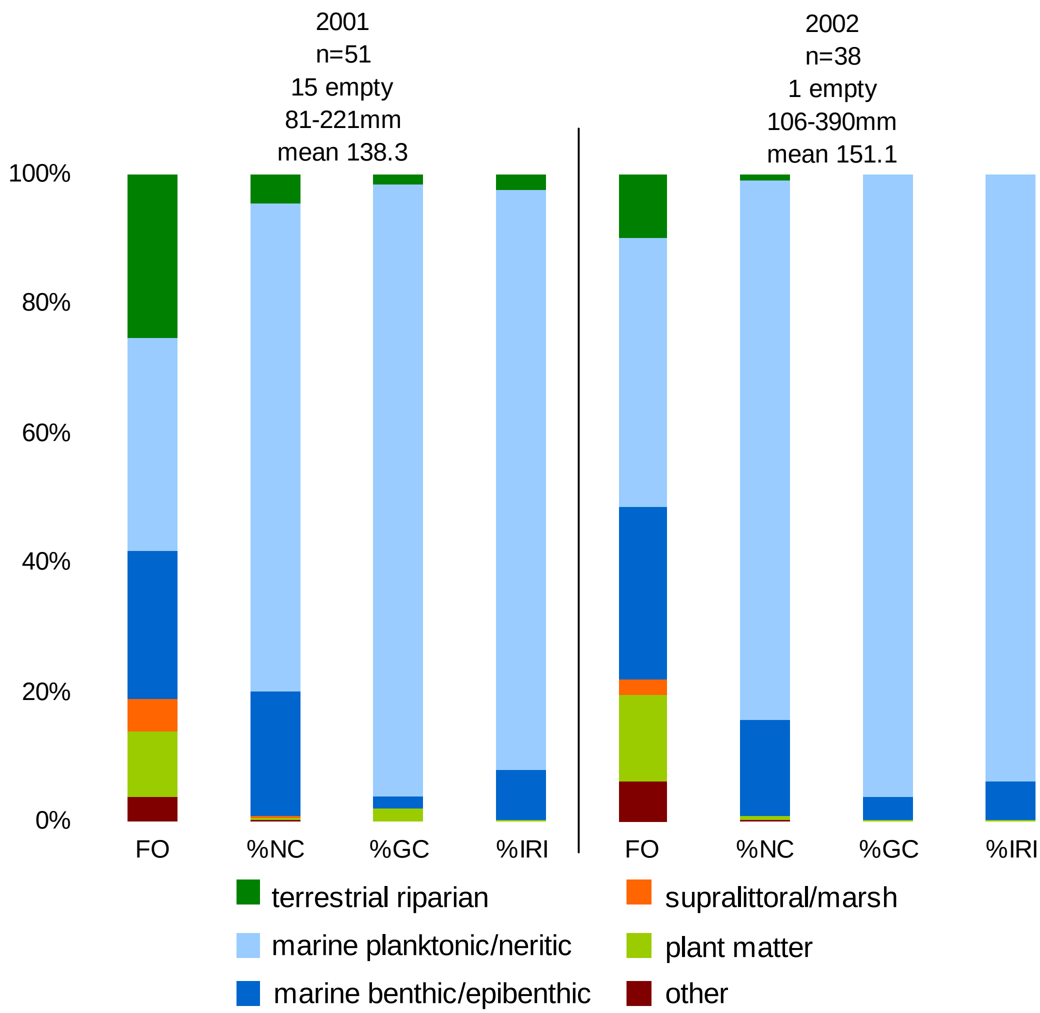


Figure 3.41. Overall diet composition (gravimetric, numerical, frequency of occurrence, IRI value) based on prey ecology for juvenile Puget Sound coho salmon from 2001-2002.

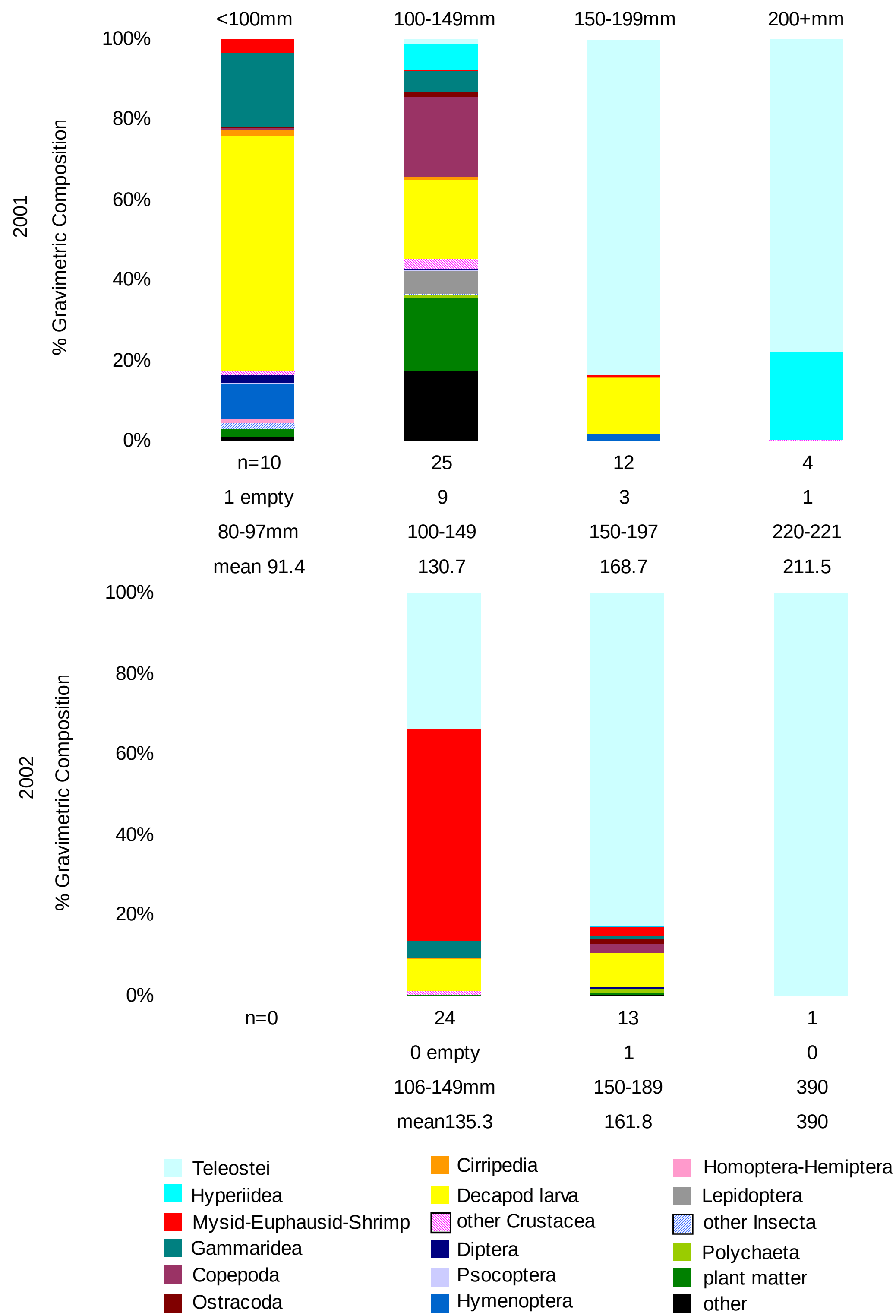


Figure 3.42. Diet composition by weight based on taxonomic groups for four size classes of juvenile Puget Sound coho salmon from 2001 and 2002.

3.1 Cutthroat Trout

A total of 56 cutthroat trout diets from 12 beaches were analyzed including 47 individuals from 2001 and 9 from 2002 (Table 3.20; Appendix 4). The size of fish ranged from 130-441 mm (FL) (Figure 3.38; Appendix 4).

3.3.3.1. Overall Diet Composition

Cutthroat trout diets were dominated by fish in both 2001 and 2002 (Figures 3.43 and 3.44). In 2002, most of these were identified as Pacific herring. Taxa that were relatively numerous in the diets but contributed little biomass included formicidae, *Cancer* crab megalopae, and the gammarid amphipod *Allorchestes* spp. in 2001, and Calliopiid gammarids and the isopod *Exosphaeroma* sp. in 2002 (see illustrations of these taxa in Appendix 1). For cutthroat diet data grouped by ecological categories, planktonic/neritic prey largely dominated the diets by weight in both years (Figure 3.45). By numerical composition, marine benthic/epibenthic prey taxa were about as abundant as planktonic/neritic prey in 2001, and dominated numerically in 2002.

3.3.3.2. Diet by Size Class

Fish dominated the prey in all of the size class groupings of cutthroat trout, except for those in the 150-199 mm size class, in which terrestrial/riparian insects, mainly Hymenoptera and Diptera, were abundant (Figure 3.46). In this group (n=27), barnacle exuviae, legs, and naupliar masses were also relatively important.

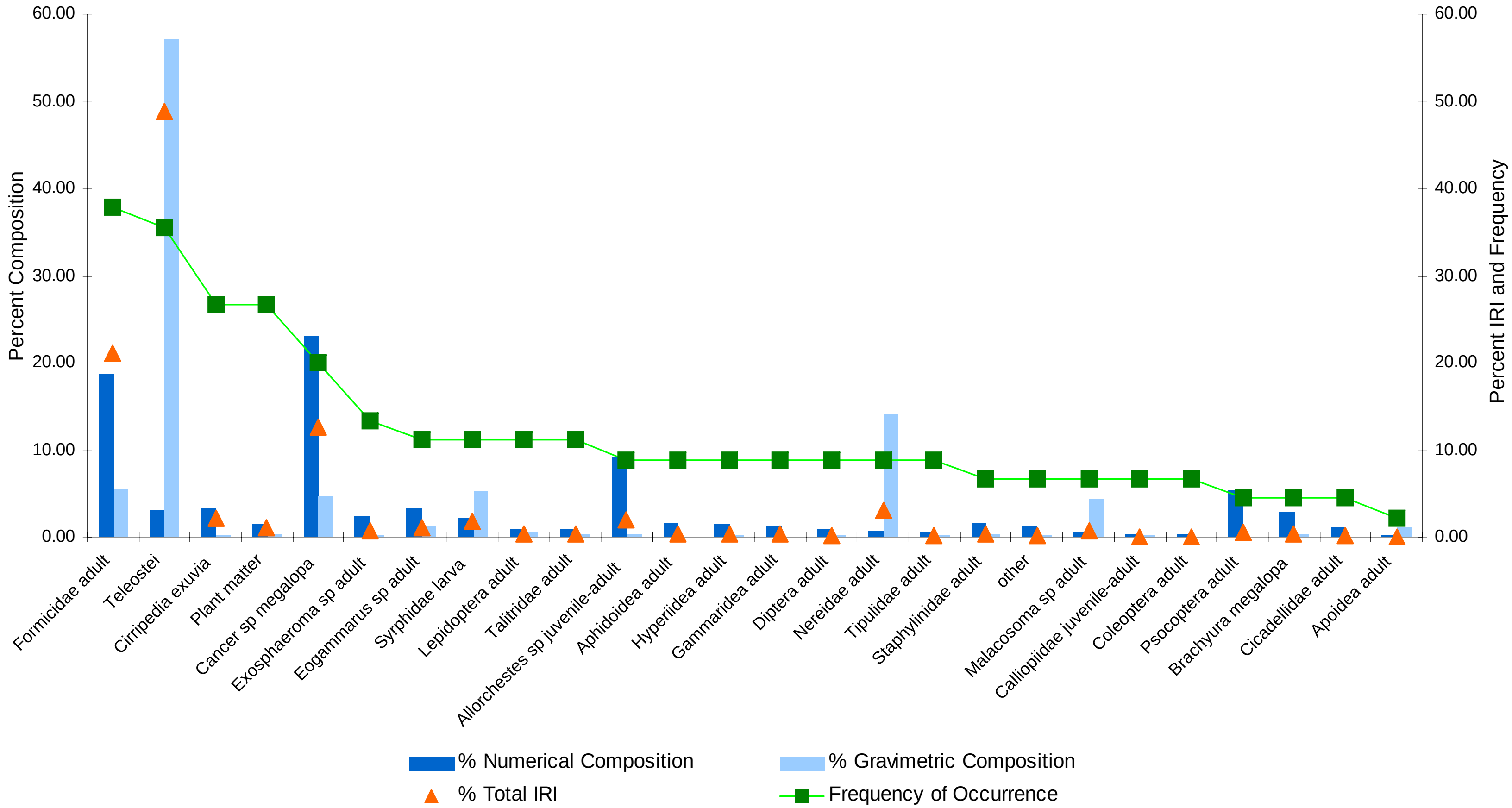


Figure 3.43. Overall diet composition (gravimetric, numerical, frequency of occurrence, IRI value) of juvenile Puget Sound cutthroat trout collected in 2001.

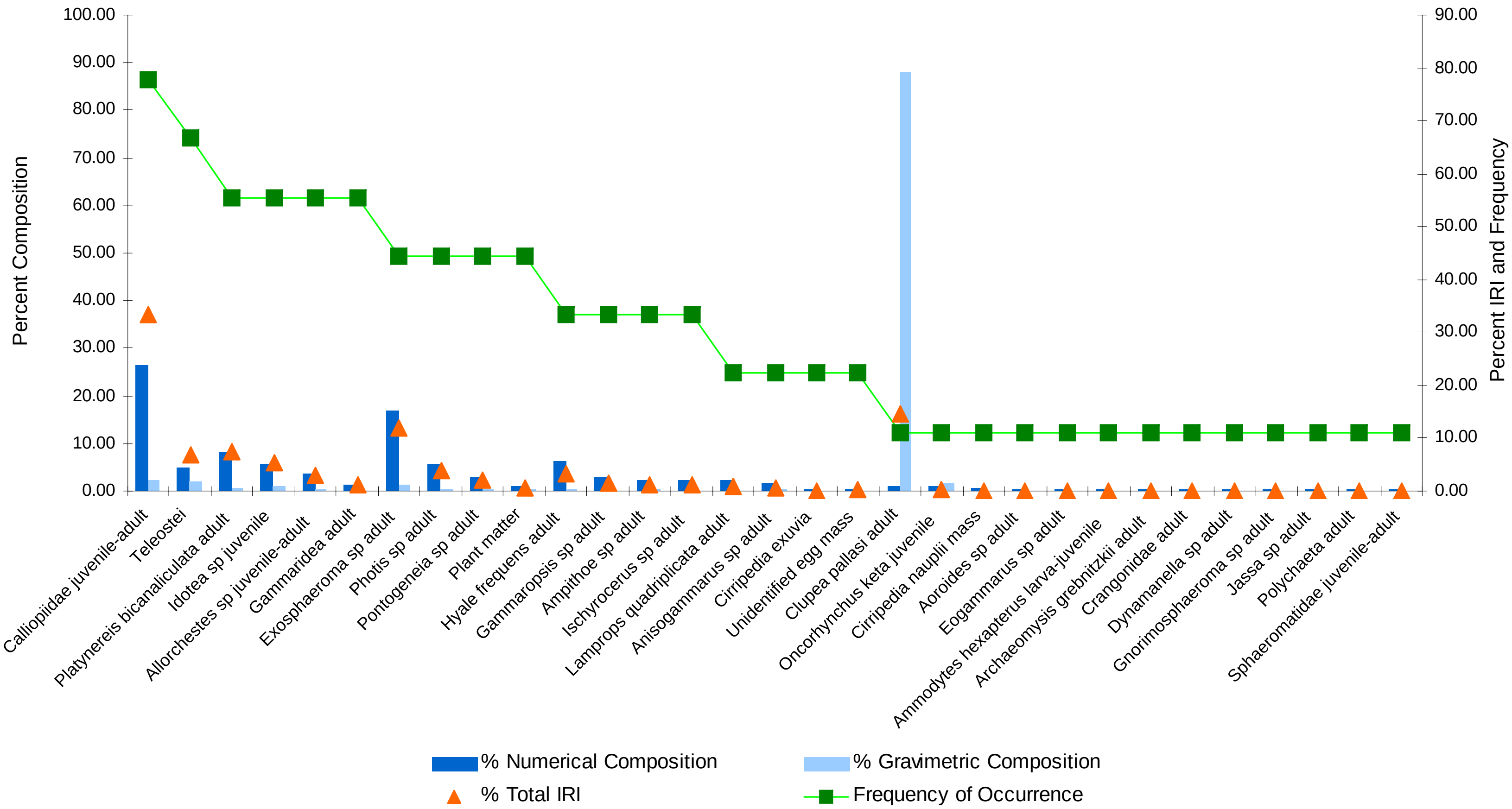


Figure 3.44. Overall diet composition (gravimetric, numerical, frequency of occurrence, IRI value) of juvenile Puget Sound cutthroat trout collected in 2002.

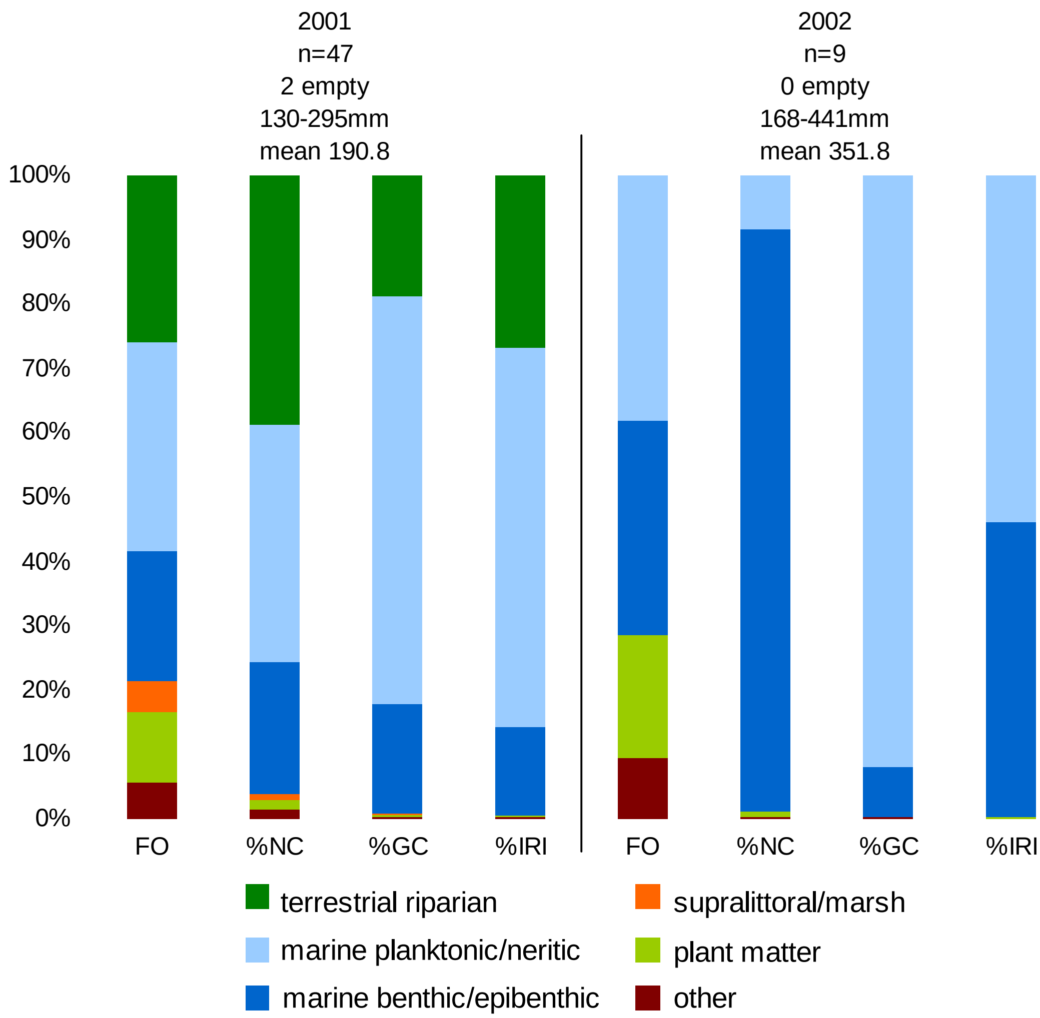


Figure 3.45. Overall diet composition (gravimetric, numerical, frequency of occurrence, IRI value) based on prey ecology for juvenile Puget Sound cutthroat trout from 2001-2002.

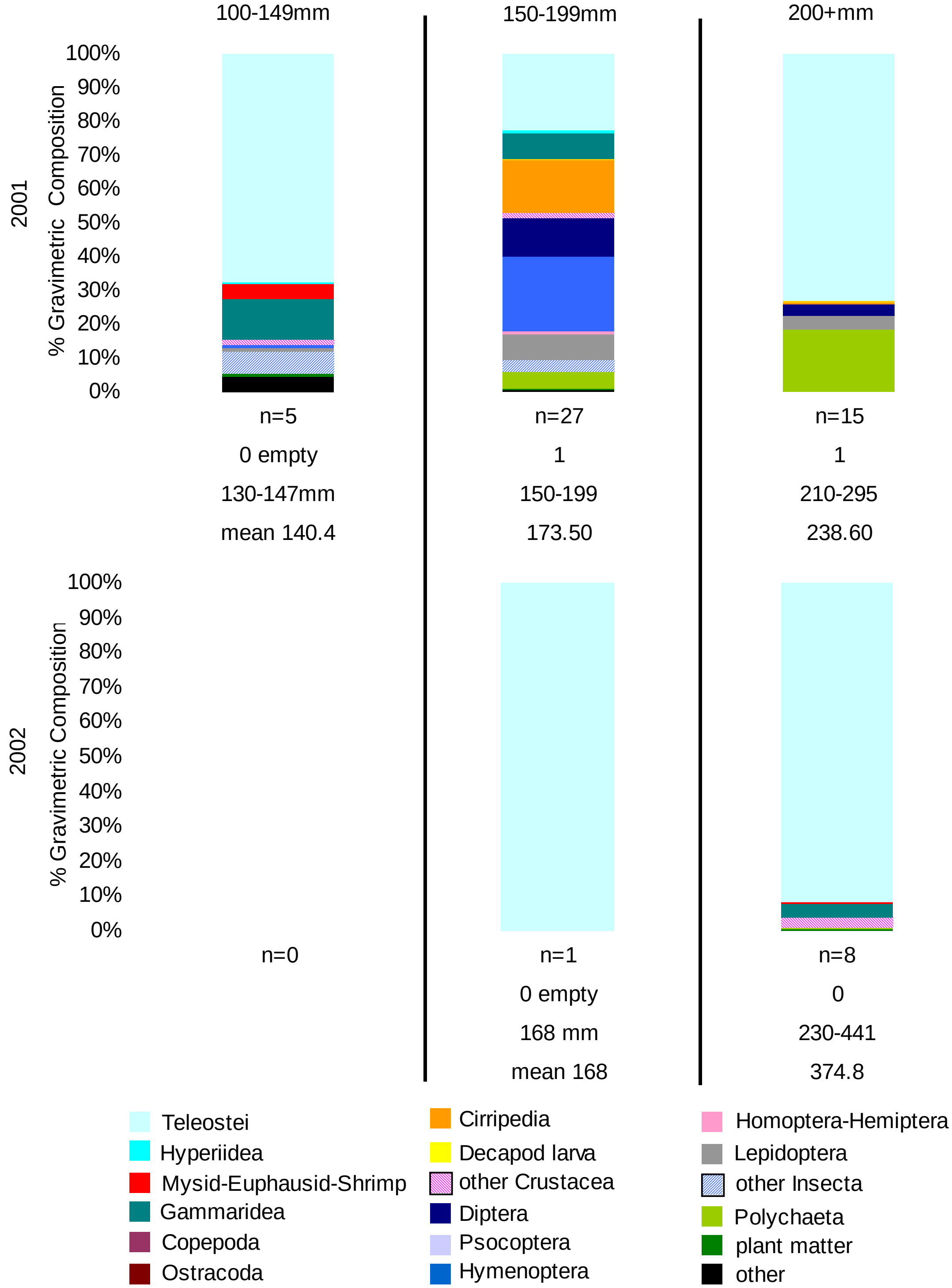


Figure 3.46. Diet composition by weight based on taxonomic groups for three size classes of juvenile Puget Sound cutthroat trout from 2001 and 2002.

SECTION 4: DISCUSSION

This study was designed to enhance and contribute to the limited information available on juvenile salmonid early marine residency in shoreline areas of central Puget Sound. The results of this study provide information on the general timing, distribution, species composition, and diet of juvenile salmon in the study area. These results have a variety of implications for salmon recovery planning and resource management actions that extend beyond salmon originating in local watersheds. For example, the mixing of multiple salmon stocks in the study area highlights the common and broad use of nearshore marine waters by salmonids originating from both local and distant watersheds. The apparent use of a complex of different habitats is illustrated by their spatial and temporal distribution, which suggests that preserving, or attempting to restore single or limited habitat attributes may be inadequate for supporting salmon in the nearshore and recovering listed species. In addition, the types of habitat responsible for prey production, the life history requirements of prey, and the seasonal and spatial patterns of prey abundance and distribution are important considerations in salmon conservation. Furthermore, considerations required to maintain or restore the larger scale ecosystem processes that form and maintain habitat for all species that are dependent upon the ecological integrity of the nearshore landscape, including adjacent riparian and upland landscapes, must also be addressed.

Distinguishing marked and unmarked salmonids in this study provided a much better understanding of relative abundance and distributions of hatchery and wild fish. In particular, the collection of CWT juvenile salmonids is valuable for enhancing the understanding of distribution, growth, rate of travel, catch composition, and origin, and is useful for understanding dynamics of multiple salmon stocks in Puget Sound.

Past attempts to fully characterizing “nearshore” use by juvenile salmonids have been difficult due to the limited sampling of segments of the nearshore (i.e., shallow, littoral/neritic waters) and sampling bias associated with each type of sampling gear (e.g., beach seine; surface tow net). All statements regarding timing and distribution, or use of the nearshore by salmonids need to be qualified to indicate the portion of the nearshore sampled, geographic area, time period, and biases associated with each sampling method. The nearshore is generally defined as that area between the lower limit of the photic zone (approximately –20 m MLLW) and the adjacent uplands (Williams et al. 2001; PSNERP 2003). Most floating beach seines used in Puget Sound only sample the upper 2 m of the water column, within approximately 30 m (offshore) of the beach. Therefore, fish that reside outside of the reach of this type of gear are not represented in the catch.

4.1. GENERAL PATTERNS OF TIMING, DISTRIBUTION, AND SIZE

Some general patterns, irrespective of species and region sampled, emerged from the data. First, each different species of salmonid occurred in the nearshore during the same approximate time period in both years, but there were differences between peak abundance and persistence of individual species. Cutthroat trout, being a year-round resident of shallow nearshore areas (Johnston 1982), were found throughout the year. Pink and chum were present at the same time at the beginning of sampling in 2002, but pink salmon disappeared shortly thereafter. There was limited overlap in the peak timing of chum with coho and Chinook abundance. The peak of coho fell in between the peak catches of chum and Chinook. The north mainland sites appeared to have a higher degree of overlap than other regions, with the peak catch of coho overlapping with both chum and Chinook in 2002. In 2001, the peak catch of coho at north mainland sites occurred in between the primary and secondary peaks of Chinook abundance. As expected, very few juvenile steelhead, char, sockeye, and Atlantic salmon were caught in either year, and pinks were only caught in 2002. Most Chinook, chum, and pink were subyearlings, while most coho and sockeye were yearlings. Cutthroat and steelhead were made up of multiple size classes.

The time/size-related patterns of persistence are illustrated in this study's catch records for all salmonids captured. Pink salmon are believed to move offshore at approximately 60-80 mm in the May-June time period (Emmett et al. 1991), which would explain why they were not prevalent in the catch. In general, Chinook tend to move offshore when they reach a size of approximately 130-150 mm, but reside for extended periods in shallow nearshore waters. Orsi and Jaenicke (1996) found Chinook larger than 130 mm when fishing in waters deeper than 30 m. Dawley et al. (1981) found mostly subyearling Chinook under 135 mm in water of 4 m depth. The findings of this study, while limited to shallow depths, appear to be in agreement with these previous findings.

4.1.1. Interannual Comparison

Far more chum and coho were caught (CPUE) in 2002 than 2001. This may be attributed to sampling bias or an increase in production of chum and coho smolts in 2002. Sampling occurred earlier in the year at the north mainland sites, which may account for more chum being caught in 2002. However, this does not explain the higher numbers of coho, since coho appear to migrate through the north mainland nearshore later than the other two regions. The north mainland was the only region where the peak abundance of coho was captured in both 2001 and 2002. This would indicate that the higher abundance seen in 2002 was not a sampling bias but was indicative of more coho present in the system. This is in agreement with Duffy (2003) who noted that higher spawning escapements and hatchery releases occurred in 2002 versus 2001.

Another notable difference between the two years was the difference in mean lengths of Chinook, coho, and chum. The lengths of these salmonids were significantly greater in 2001. Duffy (2003) also observed this pattern for Chinook and chum, but found the opposite for coho, with coho being larger in 2002. Possible reasons for differences between the two years include variability in environmental factors, negative competitive interaction between pink salmon (present during even years) and other salmonids, and/or size at release from hatcheries.

There was some seasonality to the percentages of hatchery Chinook caught in both years. Hatchery Chinook dominated the catch of Chinook in May, June, and July, while "wild" Chinook were more prevalent in the catches of August, September, and October. While the percentage of "wild" Chinook did increase over the summer, the actual numbers and CPUE of "wild" Chinook were decreasing during the same time period indicating a net movement out of the sampling area.

4.1.2. Regional Patterns

Several regional patterns were seen in the catch data. Cutthroat trout CPUE was significantly higher in both years at the northern sites than at the southern or island sites. This is likely due to a "hot spot" in that area for cutthroat trout. Even in 2002, when effort was lower at north mainland sites, and the "hot spot" was sampled only early in the season, enough fish were captured during those 5 days to influence the catch data for the 2002 north mainland region as a whole.

Though not statistically significant, more unclipped coho were caught at north mainland sites during both years than at the southern or island sites. This could be an artifact of different clipping rates and/or timing of different stocks. The greatest abundance of coho was recorded at north region sites. In the southern and island regions, the peak abundance may have been completely missed, or recorded while on the decline. This regional difference indicates either a strong variability in freshwater outmigration timing between stocks, or disparities in timing of peak usage of shallow nearshore areas between the different regions. The timing of coho captured at the north mainland sites appears to be verified by the timing of PIT tagged "wild" coho out of the WRIA 8 system (DeVries 2002 and 2003). The WRIA 8 system is somewhat unusual because it is lake-dominated, which may delay migration timing, and explain the later peak abundance seen in the north mainland region. It is also possible that this observation is an artifact of different clipping rates between coho released from WRIAs 7, 8, 9, and 10. WRIA 10 clipped 80% and 96% of coho released in 2001 and 2002, respectively (rmis.org). Whereas, the other 3 WRIAs clipped approximately 40% and 55% of coho released in 2001 and 2002, respectively.

In 2001, more "wild" coho were caught at the northern index sites than at the southern or island index sites, yet more clipped coho were caught at the southern index sites. A similar north to south pattern was noted in 2002. As noted above, this observation is likely related to differences in clipping rates amongst the nearest hatcheries, with WRIA 10 reporting the highest clipping rate.

Interestingly, there was no significant difference in CPUE of juvenile Chinook between the island sites and the north and south mainland sites. This result is somewhat surprising considering that there are no Chinook-bearing streams on Vashon and Maury Islands. Given that juvenile Chinook are believed to be primarily shoreline oriented (Williams et al. 2001), this observation suggests that their distribution patterns, and the factors that influence their distribution, are more complex than previously thought. CPUE of hatchery and "wild" Chinook was highest in the south mainland region in 2001 as a result of the large catches of Chinook at Lincoln Beach.

Chum were caught in higher numbers in the northern region. This was likely due to the close proximity of the north mainland sites to the Snohomish River system. The Snohomish River system is known to have a large chum population relative to the other river systems within the study boundary (wdfw.wa.gov/fish/chum).

Pinks were caught almost entirely at the north mainland sites. As with chum, it is assumed that these pink salmon came from the Snohomish River system since WRIA 8 does not have a population of pinks (Kerwin 2001; Haring 2002). However, given that the Green River does have a population of pink salmon, it seems likely that they would have been caught in the southern region of study had they been present in the nearshore areas at the time of sampling. It is believed that sampling did not occur early enough in the year to catch the peak abundance of pinks at the southern and island sites.

4.1.3. Hatchery Influences

Several general patterns were seen when hatchery and "wild" data were compared. First, hatchery coho and Chinook were significantly larger in size than their "wild" counterparts for both years. This finding is in agreement with Duffy's (2003) observations. Next, the timing of hatchery and "wild" Chinook and coho appeared to vary more between years than within years. For example, smaller peaks in "wild" Chinook frequently accompanied large peaks in CPUE of hatchery Chinook. This pattern, although less uniform, is also present in coho. This pattern in timing can be interpreted in several ways: (1) Hatchery release timing mimics "wild" outmigration timing and there are simply fewer "wild" Chinook and coho; (2) The low clipping rate of hatchery fish results in misidentification of hatchery fish that are classified as "wild"; (3) The pied piper affect or "sweeping" is occurring (Flagg et al. 2000); and (4) The large influx of hatchery fish into the river mouth/estuary crops down the available food resulting in all fish searching for food in the nearshore system.

Finally, when examining the timing of hatchery and "wild" fish within each region and year separately, combined with the CWT data, peaks of CPUE in each region can clearly be connected with specific hatchery release dates. This effect of hatchery releases on peak timing has been documented in other studies (Dawley et al. 1981; Duffy 2003). Therefore, it is likely that the peaks for "wild" fish observed throughout this study have been influenced to some degree by hatchery releases.

4.2. ENVIRONMENTAL INFLUENCES

Relationships were observed between CPUE of chum and coho and substrate type. The CPUE of coho was significantly higher for gravel substrates than all other substrate categories. However, it is likely that the larger number of coho caught at north mainland sites early in 2002 may bias this result since this sampling generally occurred at sites with larger substrates. Chum salmon were caught in higher numbers at sites with sand substrate. This result does not fit with what Haggarty (1997) found in Burrard Inlet, B.C., with chum caught in significantly higher numbers over gravel/cobble substrates. Given these differences and potential biases associated with the sampling methods and data collection, it could be that the results are simply a reflection of site specificity. A relationship was also observed between coho CPUE and the presence of SAV. However, sampling was not always conducted "through" the SAV, when present, due to the inability of the seine to reach vegetation at depths greater than 2 meters. This limitation becomes especially significant at higher tides. Additional sampling and more refined analyses are needed to determine fish-substrate relationships. For juvenile salmonids, it is likely that the linkages are more related to prey production, support of SAV, and other functions.

Many of the distribution patterns observed from the CWT samples suggest that oceanographic (e.g., currents) and/or atmospheric (e.g., winds) forces may play a role in juvenile salmon distribution in Puget Sound. To what extent, however, remains unclear. Bax (1981) found a positive correlation between surface flows and outmigration rate of juvenile chum salmon in Hood Canal. He also reported recaptures of marked chum salmon on the opposite shore of Hood Canal within a day of release, indicating rapid movement across open water. Moser et al. (1991) found that juvenile coho migratory progress was influenced by surface currents. Furthermore, qualitative field observations of catch in areas such as points and embayments suggest that physical forces (e.g., winds, eddies) may play a role in juvenile salmon distribution and abundance (Stober and Chew, 1984). Additional research is needed to establish linkages between movement/migration patterns of salmon with Puget Sound and the oceanography of the region.

4.3. DISTRIBUTION PATTERNS OF CWT CHINOOK AND COHO

Based on the CWT data, it is apparent that after juvenile Chinook leave their natal estuaries, they appear to disperse broadly and mix with other Puget Sound stocks to a great degree. Although the dispersal was somewhat variable within and between stocks, some patterns did emerge.

As expected, south Sound CWT Chinook were recaptured north of their origin. However, they were not caught at sample sites in WRIA 8 (northern region). The fact that they were not recaptured as frequently at the WRIA 8 sampling sites may indicate that they moved offshore, were no longer susceptible to the sampling gear, or may move through Puget Sound via an alternate route. Alternate migration patterns may be volitional, or may be influenced by oceanographic forces.

In a similar pattern, but in the opposite and less expected direction, Chinook from north Sound stocks (north of WRIA 7) moved south (and southeast) and were recaptured almost entirely at WRIA 8 sample sites. Again, these fish were not captured in the nearshore waters of WRIA 9, possibly indicating that they had moved offshore out of reach of the gear or may move through Puget Sound via an alternate route.

Also notable, was the pattern of movement across the open waters of Puget Sound. Many Chinook and CWT fish were recaptured on Vashon and Maury Islands. Yet, there are no Chinook producing streams or hatchery releases of Chinook on the islands. The recaptures of Grovers Creek, Port Gamble, and Dungeness hatchery fish on the east side of Puget Sound frequently occurred after only a very short period of time-at-large.

Somewhat unexpectedly, Soos Creek Chinook were recaptured mostly to the south of their point of entry into Puget Sound in both years, though sampling effort to the north was not equal in 2002. This observation was surprising in that it demonstrated movement, for some individuals at least, deeper into Puget Sound instead of towards the entrance to the Pacific Ocean. The Wallace River Chinook were caught in almost equal numbers in WRIAs 8 and 9, but were caught almost entirely in WRIA 9 after August in both years. Unfortunately, few Chinook were coded wire tagged in WRIA 8 during the two years of the study, which limited the ability to identify any trends in their distribution.

The lower number of CWT coho samples provides a more limited picture of coho distribution in the study area. It is likely that earlier sampling, or use of a different sampling method would have resulted in the collection of more coho. Since most coho typically enter Puget Sound earlier than this study's sampling period, and they enter at a larger size, it is likely that they were not as susceptible as Chinook to the sampling gear. It is generally believed that coho are not as shoreline oriented (i.e., shallow water) as Chinook (Meyer et al. 1981) and that larger juvenile salmon tend to move farther offshore. Therefore, this study provides only a partial representation of coho distribution. However, there were representatives of north Sound and south Sound stocks recaptured in the study area, indicating northern, southern and cross-Sound distribution (e.g., Vashon/Maury Island samples) consistent with CWT Chinook movements. Earlier seasonal sampling and "offshore" sampling would greatly benefit the understanding of coho timing and distribution.

Clearly, some juvenile Chinook salmon do not simply leave their natal streams and make unidirectional migrations out of Puget Sound. Chinook have the most complex life-history patterns for emigration, with 36 distinct life history pathways (Wissmar and Simenstad 1998). The number of trajectories, or emigration patterns displayed by Chinook in the study area is unknown and, while heavily "masked" by dominant numbers of hatchery fish, are primarily composed of "ocean type" Chinook, which are more dependent upon estuarine and shoreline areas for rearing. The data collected as part of this study showed complex movement patterns, with many northern stocks of Chinook moving south or from the west to the east side of the Sound. Essentially, many stocks were moving deeper into Puget Sound, rather than moving directly out of the Sound. Other studies have found similar results, but did not necessarily have enough data to see general patterns. For example, Salo et al. (1967) recaptured pigment-marked fish originating from the Green River and the Snohomish River systems in South Puget Sound (Case Inlet, Carr Inlet, Point Defiance and Pickering Passage). The pattern of recoveries in Puget Sound seems to indicate migration by fingerling Chinook southward in the Sound from Everett Bay and Elliott Bay (Salo et al. 1967). Pearce et al. (1982) recaptured CWT Soos Creek hatchery fish in the Nisqually estuary. Similarly, Meyer et al. (1981) recaptured a number of marked fish from outside of the Hylebos waterway. More recently, several other studies have collected similar data on CWT Chinook providing more evidence that Chinook stocks mix in the nearshore. Duffy (2003) recaptured CWT fish in the south Sound from the Skagit River system and Hood Canal. Fresh et al. (in prep), conducting beach seine and surface tow net surveys in Sinclair Inlet, caught many CWT Chinook from outside their study area.

4.4. CWT GROWTH

Growth rates (determined from changes in FL), calculated from the subsample of 2001 and 2002 CWT recaptures, ranged from 0.52 – 0.59 mm/d, which is similar to rates reported for Coos Bay fall Chinook by Fisher and Pearcy (1989). Fisher and Pearcy (1989) also provide a review of similar findings in other geographic areas (e.g., Dawley et al. 1986; Levings et al. 1986), but also note that these estimates are lower than those reported by Healey (1980a) and Argue et al. (1986). Although one would expect to find some variability in growth of juvenile Chinook from different geographic areas and of different genetic stocks, other variability could be due to differences in size classes sampled, time-at-large, density, or food supply. The greatest confounding factor in this study is the large number of Soos Creek hatchery fish that exhibited negative growth. The cumulative growth rate would have been higher if these samples were eliminated from the calculations. It is possible that food supply limitations, or other environmental factors, could have resulted in a small amount of negative growth, but the most likely explanation is poor measurements or estimates of length and weight by the hatchery personnel at the time of release.

4.5. CWT TIME-AT-LARGE

Fish from specific hatcheries were recaptured after varying periods of time. For example, Grovers Creek hatchery Chinook were all caught within 30 days (many as early as 4 days). Similarly, most Soos Creek hatchery fish were caught within 2-4 weeks. The relatively large number of Soos Creek recaptures after a short period of time-at-large may be explained by the proximity of the natal river (Green River) to the sampling sites. However, approximately 30% of the Wallace River hatchery Chinook were recaptured 60 days after release. It is not clear if this is reflective of longer freshwater residency, or persistence in marine nearshore waters. Miller and Sadro (2003) determined that juvenile coho exhibited variable residence times in the lower estuary of Winchester Creek, Oregon, depending upon the time of year (spring vs. fall) they moved down river and into the estuary. The majority (75%) of fall/winter migrants resided from 12-40 days with the remainder residing 50-84 days, whereas 75% of the spring migrants resided 2-10 days with the remainder residing 26-28 days. Therefore, it is important to know migration rates within each segment of the migration route and to have a good understanding of residence times for fish with different trajectories within a particular system.

Similar problems arise when attempting to interpret distances and rates of travel for mark/recaptured fish. Estimates provide a minimum rate of travel for juvenile Chinook that ranged from approximately 3-4 km/day. Although these estimates of rate of travel fall within the ranges reported by some investigators (e.g., Bax 1983 and Orsi et al. 2000), they are significantly lower than those reported by others. For example, Dawley et al. (1981) and Pearcy and Fisher (1987) reported highly variable migration rates for juvenile coho that ranged from 14-23 km/day. These rates are for various stocks and systems (Pacific Ocean and Columbia River) and are not measured in an estuary similar to Puget Sound, making it difficult to compare results. Undoubtedly, the rates are somewhat variable between freshwater, estuarine, and marine systems, and vary by species, stock, and size of fish.

4.6. DIET

The diet analyses provide a comprehensive view of what juvenile Chinook are eating when utilizing shallow nearshore areas of the central Puget Sound shoreline. It is important to note, however, that juvenile salmonids are highly migratory, use a diverse array of habitats that change over time, and that digestion rates are variable due to temperature and digestibility of the prey. Therefore, it is difficult to identify exact sources of prey without conducting studies focused on identifying feeding location and prey productivity of particular habitat types. In addition, the variability in digestion rates may cause particular prey items to appear more important due to the slow digestion rates of particular insect body parts (Hyslop 1980). Size, weight, caloric value, and seasonal availability of individual taxa are also important considerations when evaluating fish diets (Duffy 2003). Although this study was not designed to address all of these important considerations, it does provide new information on juvenile salmonid diets, including the relative importance of specific prey taxa, seasonality and diversity of prey, and relationships between fish size, prey type, and ecological linkages (categories) to sources of prey.

4.6.1. Chinook

Most studies of juvenile Chinook salmon feeding habits have been conducted during their early out-migration through and residence in estuaries near river mouths. This is reflected in the results of these studies, which have shown diets dominated by typical tidal fresh water and euryhaline invertebrates (Healey 1991). A few studies of feeding in higher salinity habitats have found that juvenile Chinook diets contained a different prey spectrum that included more terrestrial insects and marine invertebrate plankton such as euphausiids, crab larvae, and pelagic amphipods (Fresh et al. 1981; Healey 1980b, 1982; Duffy 2003). This study expands on these earlier findings by analyzing stomach contents of fishes collected outside of river estuaries, at marine beaches of Puget Sound across multiple sites and times.

The overall results presented here point to three general habitat types—terrestrial/riparian, shallow benthic/epibenthic, and pelagic—as the most important prey production/foraging areas for juvenile Chinook salmon in shallow marine nearshore areas of Puget Sound. Prey taxa characteristic of emergent marshes (e.g., chironimid pupae and emergent adults) or marine supralittoral habitats (e.g., talitrid "beach-hopper" amphipods) were not important in the Chinook diets from this study. The lack of marsh-dwelling insects is not surprising considering that juvenile Chinook salmon in this study were caught along marine beaches. The reasons for low numbers of marine supralittoral organisms in the diets is unknown, but could include relatively short exposure time of the fish to the upper beach habitat, (i.e., only at high tides), behavior of potential invertebrate prey to avoid predation (e.g., talitrid amphipods staying above the high tide line), or habitat loss or degradation due to alteration of shorelines (Sobocinski 2003).

Insects characteristic of terrestrial vegetated habitats such as psocoptera, homoptera, and hymenoptera dominated the numerical composition of juvenile Chinook diets, especially those in the size range from 110-149 mm. These insects could have entered Puget Sound via either wash out from rivers or from terrestrial vegetation. However, the fact that most of the insects in the diets were fully developed winged adult forms, and that the sampling sites in the study were not located in close proximity to major rivers suggests that they were likely wind-blown or fell from overhanging vegetation rather than entering Puget Sound via river flow. Brodeur (1989) reached a similar conclusion for terrestrial insects that were important in juvenile Chinook and coho salmon 4-47 km off the Oregon and Washington coasts. In his study, an assemblage of terrestrial insects similar to those found in this study were numerically prominent in coho and Chinook salmon diets in July and September. In a study of juvenile salmon feeding in Hood Canal, Washington at a central, deep station and a shallow nearshore station, Bollens et al. (in preparation) found larger percentages of insects and spiders in fish captured at the nearshore station. Field observations of insects along the shoreline suggests that many of these insects are produced in areas close to the water.

Along with earlier, largely unpublished work, the results of this study point to vegetated shoreline habitats as an important source of juvenile Chinook salmon prey. Because much of the Puget Sound shoreline has been altered by armoring and backshore development, there may be a decreased input of terrestrial-derived salmon prey to Puget Sound. A recent study of insect fallout from vegetation on Puget Sound shorelines found that beaches altered by armoring and development resulted in consistently lower taxa richness than at more natural, non-armored, and adjacent beaches (Sobocinski 2003). Also, in that study, several prominent taxa of shore-dwelling insects and amphipod populations were significantly less dense at the human-altered sites than at the natural beaches. The magnitude of loss of terrestrial input of prey resources for juvenile Puget Sound salmon derived from shore vegetation is unknown, and some of this input could come from farther inland. Large mobile insects such as tent caterpillar moths (this study) and spruce budworms (Locke and Corey 1986; Brodeur 1989) that could have been produced inland, even occur in salmon diets many kilometers off shore. Long-distance overland dispersion of insects has been demonstrated by Caceres and Soluk (2002), but Russel and Wilson (2001), using doppler radar imaging of insect masses, concluded that their data supported the hypothesis that insects respond behaviorally near coastlines to avoid being blown out to sea. A number of studies of marine neuston and oceanic insect trapping have established that many terrestrial insects are blown out to sea (up to 800 km away from land), and probably provide a considerable amount of organic matter to the surface water (Bowden and Johnson 1976; Cheng and Birch 1978; Yoshimoto and Gressitt 1960). Field observations made in conjunction with this study noted the presence (and seasonal abundance) of tent caterpillars and other insects associated with shoreline vegetation, which corresponded to when they were found in Chinook diets. Seasonal abundance and diversity of insect neuston has been observed in a number of studies (e.g., Lock and Corey 1986), which reflects their seasonal patterns of emergence and availability. Regardless of whether or not most of the insect prey in Puget Sound is produced along the shoreline, or further back from shore, salmonid prey production appears to be an important function of marine riparian areas and vegetated backshore. Therefore, preserving, enhancing, or restoring shoreline vegetation may play a role in salmon survival and recovery strategies.

A link between juvenile Chinook salmon diets and shallow vegetated habitats is evident through their concentrated feeding on the polychaete *Platynereis bicanaliculata* early in the season. For the smallest Chinook salmon studied (<90mm), this species usually dominated diet contents weight. *Platynereis bicanaliculata* is an herbivorous polychaete that builds tubes on eelgrass and macroalgae and is common in Puget Sound in marine subtidal mixed-coarse, mixed fine, and cobble substrates and in estuarine subtidal sand and mixed fines, substrates (Dethier 1990). It enters the water column in synchronized reproductive swarms (Woodin 1977; Fong 1993; Minoru et al. 2003). Juvenile Chinook were feeding mainly on *Platynereis epitokes* (reproductive forms occurring in the water column). Although the life history stage of polychaetes in the diets was not explicitly recorded, it was noted that when intact, the Platynereis in the stomachs usually had characteristic body differentiation characteristic of the epitoke stage (see Appendix 1). Because invertebrates from the substrate or water column were not sampled, it is not possible to determine whether or not the dominance of *Platynereis* in Chinook diets earlier in the year was due to higher prey densities during those times, or to selectivity by the fish. Likewise, it is not known why the *Platynereis* diet dominance was approximately one month later in 2002 samples as compared to 2001. Ecological studies of *P. bicanaliculata* in an eelgrass bed in central Japan showed that epitokes occurred from late February to mid-November, with peak epitokal swarming activity in the warm season, and differences in peak abundance among years (Fukao 1996). Therefore, its seems likely that juvenile Chinook salmon in this study were taking advantage of *Platynereis* when it was swarming in the water column. Verification of this would require that plankton sampling be conducted along with the collection of diet samples.

Another planktonic organism found in the diet of Chinook and coho salmon was crab larvae (zoea and megalops phases). Crab larvae are most abundant in Puget Sound in the late spring-summer time period. During the earlier phases, zoea tend to be epibenthic, but may be found throughout the water column, whereas the megalops move inshore just prior to settling out in shallow nearshore areas (Don Velasquez, WDFW personal communication). The timing of this behavior corresponds with the seasonal abundance of crab larvae in fish diets. Other benthic/epibenthic taxa that occurred in the juvenile Chinook diets may have also been obtained during swimming stages of their life history. For example, several of the common prey gammarid amphipods that are commonly associated with algal habitats (e.g., *Calliopiidae, Allorchestes* spp, *Anisogammaridae*) were regularly observed in the plankton or swimming near shore (Bousfield and Hendrycks 1997; Hendrycks and Bousfield 2001).

Another common benthic prey item in the samples of juvenile Chinook diets was appendages and naupliar masses from barnacles. While barnacle exuviae are common in the diet, intact appendages and nauplii have not been previously reported as common prey items. Apparently, the salmon were feeding on naupliar masses as they were being released by the barnacles, before they had broken apart. In some cases the naupliar masses were still encased in membranes. In other cases, they appeared to be attached to exuviae. Most of the benthic/epibenthic prey that the juvenile Chinook consumed are associated with eelgrass, kelps, and other macroalgae. Whether these prey originated in kelps and algae that require hard substrate, or in eelgrass that requires finer substrates, is not known. Substrate types and their relationship to prey production and other functions (i.e., primary and secondary productivity) deserve further study regarding their value as juvenile Chinook salmon habitat.

Because juvenile Chinook salmon are oriented to shallow water when they are small (Healey 1991), their predation on zooplankton from Puget Sound beaches may have represented opportunistic feeding, rather than an indication that the salmon were spending most of their time in that habitat. For example, switching feeding from aquatic insects to terrestrial insects and zooplankton (e.g., Daphnia) by sub-yearling Chinook salmon entering reservoirs in the Columbia River was attributed to opportunistic feeding on the high density of those prey in the reservoirs (Rondorf et al. 1990). Before the Chinook in this study began feeding on fish later in the year, they fed mainly on plankton taxa that are known to swarm or become entrained in fronts on the water surface.

From a graphical analysis of the juvenile Chinook diets in the three geographical regions of central Puget Sound (North, South, Vashon/Maury Islands), few differences were observed between the regions. Also, regional differences were dissimilar between 2001 and 2002. One exception was that the fish from the northern group of sites consumed fewer polychaete worms and more terrestrial insects than at the other two site groups. Duffy (2003) had similar findings with higher amounts of insects in the diet of Chinook found north of sites in this study compared with sites found south of this study's area. Because prey assemblages were not sampled, it is not known if these differences were due to differences in prey availability among the site groups. One way to partially answer this question would be to conduct a multivariate analysis of the diet data along with habitat data from beaches where fish were captured (e.g., beach slope, submerged/intertidal vegetation, supralittoral/backshore vegetation). This type of analysis could further elucidate site-related differences and provide explanations for them. In addition, sampling of the water column, quantifying caloric content of prey, and an integration of prey life history characteristics would greatly advance the understanding of Chinook diet, preferences, and habitat requirements.

Preliminary analysis of 2002 hatchery and wild Chinook salmon diets suggests that there was little difference in feeding between these two groups. There was one exception, for fish sampled in May, when hatchery Chinook had more euphausiids and barnacle exuviae in their diets and wild fish fed on more gammarid amphipods. This may be because the earlier out-migrants had not acclimated to natural feeding conditions (Myers 1980), but the results should be interpreted with care because the sample size for wild fish was small (n=6). For the remaining monthly comparisons, differences in diet between hatchery and wild fish were subtle, and consisted mostly of qualitative differences in ecological prey groupings (e.g., terrestrial insects made up of fewer psocoptera and more hymenoptera in hatchery Chinook captured in September). For the most part, the data from this study suggest that juvenile hatchery and wild Chinook utilize the same prey resources when they occupy nearshore habitats in Puget Sound. Given the temporal and spatial overlap of marine shoreline use by hatchery and wild Chinook, and the similarity in diets, it is likely that hatchery and wild fish compete for the same resources.

4.6.2. Coho

Findings that juvenile coho fed mainly on zooplankton before switching to fish at larger sizes is consistent with findings from previous studies in Puget Sound and elsewhere (Sandercock 1991, Fresh et al. 1981). In juvenile coho salmon captured at both north and south Puget Sound sites, Fresh et al. (1981) found that juvenile coho salmon fed mainly on crab larvae, euphausiids, and pelagic amphipods. Coho feeding on planktonic/nektonic invertebrate taxa appears to persist even after they switch to consuming mostly fish in the ocean off of Oregon and Washington (Brodeur and Pearcy 1990, Brodeur et al. 1992). Coho in this study fed on few terrestrial/riparian insects, but at least one other study found that insects were important prey for coho during early residence in Cook Inlet, Alaska (Moulton 1997).

However, in that study intensive feeding on surface insects was attributed to the high turbidity of the water.

Salmon ecology and the effects of habitat degradation on juvenile salmon in estuaries and nearshore marine habitats in Puget Sound and other waters in the Pacific Northwest are relatively well studied. In contrast, the ecology of juvenile salmon such as coho that feed in water column habitats of Puget Sound are poorly known. Brodeur et al. (1992) suggested that juvenile coho and Chinook salmon off of Oregon and Washington experienced planktonic food limitation during years of unusually low productivity (e.g., El Niño). Unfortunately the differences and similarities between Puget Sound and other coastal environments are poorly known, because quantitative studies of the zooplankton assemblage in the Puget Sound region are rare and quite limited in scope, consisting of several unpublished student theses (Dempster 1938; Hebard 1956; Damkaer 1964; Dumbauld 1985) and a few other studies (Bollens et al., in prep.; Giles and Cordell 1998). Understanding the ecology of planktivorous salmonids such as Puget Sound coho salmon will require considerable additional work on plankton biology, productivity, oceanography, and other environmental conditions that affect planktonic prey.

4.6.3. Cutthroat

Predation on other juvenile salmonids (especially pink and chum salmon) and their eggs has been recorded often for coastal cutthroat trout (Jauquet 2002). While fish dominated cutthroat diets in this study, juvenile salmon (chum) were found in only one fish (from Meadowdale beach in May, 2002), and most of the fish that were identifiable in the diets were Pacific herring. In 2001, most cutthroat samples were taken during times that did not coincide with juvenile chum salmon outmigration, which may explain the discrepancy between this study and Jauquet (2002). For cutthroat trout caught when adult or juvenile salmon were not present, Jauquet (2002) found that diets were more similar to those found in this study, having much higher proportions (by weight) of invertebrates and marine fish. Results for smaller size classes of cutthroat trout were also similar to those of Jauquet (2002), who found that cutthroat <300mm had fewer fish and more invertebrates in their diets.